

The Journal of the Indian Botanical Society

Vol. XL

1961

No. 2

ECOLOGY OF TEMPORARY POOLS DURING DRY PHASE*

I. Structure of Soil and Plant Community

BY L. P. MALL

University of Saugar, Saugar, India

(Received for publication on September 2, 1959)

INTRODUCTION

IN India low-lying areas, including temporary ponds and pools, have been ecologically investigated by a few workers. Dudgeon (1920), in his study of the ecology of the Upper Gangetic plain, clearly recognised a distinct wet meadow community represented, for the most parts, by small plants.

Misra (1946) studied the ecology of low-lying lands round about Benares. He has described the composition of the community together with the causative factors governing its development.

Ratnam and Joshi (1952) studied the vegetation near about a temporary pond at Pilani. They have also described the plant community at the bottom of the pond during its dry phase.

Daubenmire (1942) has made an intensive study of the vegetation of South-Eastern Washington adjacent Idaho. He showed that the open low-lands in flood plains of wider valleys "supported a rank growth of grasses and forbs which comprised a floristically complex community".

Polunin (1934, 1935), in his study of the vegetation of Akpatok Island, has included dried up beds of pools of the area. He showed that beds of very shallow tarns of flooded areas, which have never been anywhere more than a foot or two deep, get dried up soon leaving bare areas, which get well vegetated. Colonisation takes place quite early in the season when the moisture supply is adequate.

* Part of the thesis approved for Ph.D. degree by the University of Saugar.

Michelmore (1939) studied small valley grasslands of Tropical Africa. Soils of this area, as described by him, are variable. In drier climates there is extreme desiccation, causing cracks in dark clays. At the same time there is water-logging too in some parts of the year. The tree growth is avoided due to such fluctuating conditions.

Kassas and Imam (1954) have described the vegetational features of wadi, *i.e.*, dried river-bed in a desert area. The habitat represents an extreme type of fluctuating conditions. It gets flooded for 2-3 days during rains and dries afterwards.

The present work aims at ecological study of temporary ponds and small depressions at Saugor (India), during their dry phase. These get filled up with rain-water, during the monsoon season (Plate III), which may stand till November-December. With late rains in October the deeper ponds may not dry till even January. However, when they dry up their beds bear a herbaceous vegetation (Plate III).

PHYSIOGRAPHIC FACTORS

Location and General Features of the Ponds and Depressions

The first pond (spot 1), which covers an area of nearly 220 sq.m. is located in Tili village (Text-Fig. 1). Its maximum depth is 1.12 m. The second pond (spot 2) is situated in the cantonment area. It covers about 1,800 sq.m. with a maximum depth of 1.5 m. The third pond (spot 3), with an area of 80 sq.m., is located near Makronia Railway Station. It is shallower than the other two. The fourth pond (spot 4), on the Patharia hillock, has an area of nearly 170 sq.m. and is 1.1 m. deep. The rest of the depressions (5-19) studied are smaller in size with areas 10 to 15 sq.m. and lie along the roadside (Text-Fig. 1). Their depth varies from $\frac{1}{2}$ to 1 metre.

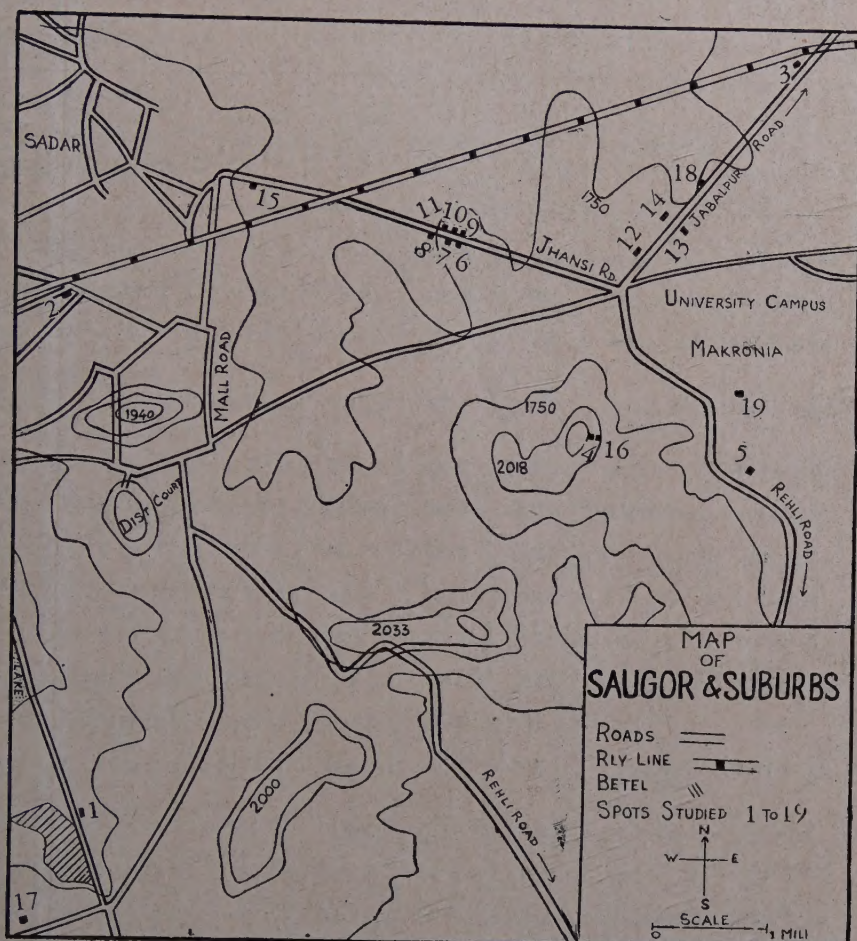
History of the Ponds and Other Depressions Studied

All the depressions except No. 3 are fairly old and must have been dug at least a hundred years ago. The soil and the underlying rocks were removed for the purpose of constructing road and houses. Pond No. 3 was dug out some fifty years back, when the railway line, joining Bina and Katni, was constructed. However, the soil covering their beds is not as old because they are periodically redug for the repairs of roads and new deposition of eroded soil from the adjacent land takes place. Only spots 1 and 2 seem not to have been disturbed so often, as the bed soil is quite old.

Physical and Chemical Characteristics of the Soil

The soils were analysed for various characteristics as given by Piper (1944) and Daubenmire (1947).

(a) *Colour*.—The soils are all black except that of depression No. 17, which is somewhat gray-coloured, overlying Vindhyan red sandstone.



TEXT-FIG. 1.

(b) *Texture*.—The soils are transported by rain-water collecting into the pools during the monsoon. The result of mechanical analysis is given in Table I. The soils fall into two types, viz., clay and silty clay. They form very deep and wide cracks on drying. The cracks may be, sometimes, 15 cm. or more wide on the surface and more than 1.2 m. deep. They begin to appear as soon as the soil moisture is lost beyond the field capacity, i.e., below 48 to 50%. Root penetration and infiltration of water are difficult through the heavy soils. On account of the clayey bottom the ponds and pools are able to retain accumulated water above their surface for a long time.

(c) *Pore space*.—The total pore space, including capillary and non-capillary, is very high ranging between 59.2 and 71.2% (Table I) The

TABLE
Soil characteristics

Spot No.	Date of collection	Locality	Depth of soil in cm.	pH	Carbo-nate content (%)	Moisture content (%)	Maximum water-holding capacity (%)	Soluble phosphate parts per million
1	21-3-1954	Tili ..	10	7.90	1.22	24.1	59.8	28.9
2	16-3-1954	Cannt. ..	10	7.95	9.85	26.6	50.9	45.5
3	19-2-1955	Makronia Rly. Stn.	10	6.95	1.30	27.7	45.1	31.0
4	20-1-1954	Patharia Hillock	10	7.25	0.30	36.4	45.1	11.3
5	20-1-1954	Rehli Road	10	7.25	3.75	22.1	47.3	67.1
6	3-3-1954	Jhansi Road	10	7.20	10.50	14.0	44.0	25.0
7	3-3-1954	„ ..	10	8.10	5.90	22.7	48.9	25.0
8	3-3-1954	„ ..	10	8.64	11.50	16.5	47.2	17.5
9	5-3-1954	„ ..	10	8.44	7.50	18.4	43.9	12.5
10	5-3-1954	„ ..	10	8.60	9.15	16.5	45.3	12.5
11	5-3-1954	„ ..	10	8.64	4.25	18.9	44.3	17.5
12	13-3-1954	Jabalpur Road	10	8.02	5.40	27.9	44.2	27.5
13	13-3-1954	„ ..	10	8.13	4.10	16.5	43.5	25.0
14	13-3-1954	„ ..	10	8.20	2.70	24.9	45.2	52.5
15	16-3-1955	Jhansi Road	10	7.70	2.00	07.0	57.9	72.0
16	3-4-1954	Patharia Hillock	10	6.60	0.15	14.9	48.2	87.5
17	3-4-1954	Tili ..	10	6.64	1.95	12.4	39.2	52.5
18	20-2-1955	Jabalpur Road	10	8.00	14.30	20.1	46.5	72.0
19	31-5-1955	Makronia ..	10	7.50	3.20	08.25	50.3	30.6

* Results are based on an average of two determinations.

I
of spots 1-19*

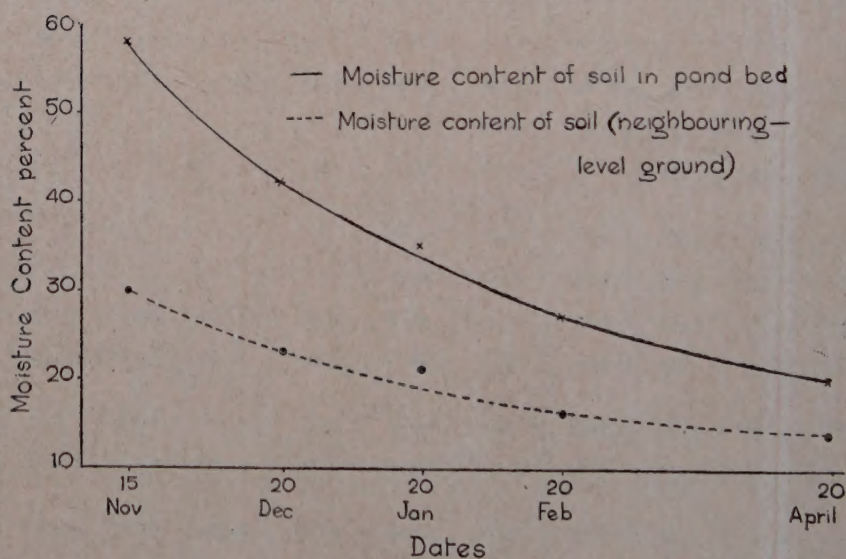
Nitrate parts per million	Iron parts per million	Calcium (%) exchange- able	Organic matter (%)	Pore space (%)	Total sol. salts mg. per 100 gm.	Gravel (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
13.5	3.16	0.96	2.38	63.1	55.0	0.34	0.62	1.29	46.46	51.39
13.5	4.17	4.77	3.52	67.3	108.0	0.00	0.60	6.19	60.25	32.96
13.0	3.20	0.76	3.93	67.2	67.0	0.00	0.55	1.09	40.60	58.30
25.0	3.41	0.60	3.59	71.2	151.0	0.00	0.11	0.90	39.69	59.30
25.0	0.83	1.75	2.27	62.1	120.0	14.14	6.71	0.57	30.95	47.62
5.0	2.25	1.92	2.43	63.6	120.0	4.92	5.80	2.62	39.04	47.62
10.0	3.16	1.65	1.52	61.0	98.0	1.38	2.47	2.93	40.06	53.16
Traces	3.67	4.42	2.13	59.5	50.0	1.30	1.60	2.71	45.45	48.90
02.5	2.88	3.27	1.69	65.7	80.0	0.95	2.49	2.03	47.26	47.27
Traces	3.45	3.90	1.02	63.0	40.0	1.48	3.33	2.72	45.70	46.77
5.0	3.58	3.20	3.12	66.6	50.0	..	..	..	..	..
5.0	2.67	3.53	2.37	65.2	40.0	..	..	..	..	..
5.0	2.50	4.80	1.82	59.2	45.0	..	..	..	..	..
10.0	2.67	2.60	4.72	61.6	60.0	..	..	..	..	..
32.5	3.75	2.15	3.72	61.6	50.0	0.20	3.78	0.50	43.30	52.22
60.0	5.80	0.42	4.94	70.1	140.0	0.00	0.11	0.90	39.69	59.30
40.0	4.72	1.82	2.02	68.1	61.0	9.70	15.64	7.60	35.92	31.14
52.0	3.72	5.13	2.73	59.4	144.0	4.00	3.93	3.93	34.76	53.40
31.4	4.15	0.92	2.31	64.0	92.0	0.10	0.21	0.70	42.30	56.60

capillary pore space, in the beginning of the dry phase, remains filled up with water and aeration is poor but as it reaches a moisture level lower than the field capacity, the development of cracks improves aeration.

(d) *Carbonate content.*—Varying amounts of carbonate have been found and in most cases it is quite high, ranging from 0.15% to 14.30% at a depth of 10 cm. (Table I).

(e) *Water relations.*—The maximum water-holding capacity of soil was determined for soils collected from 10 cm. depth. The values range from 39.2% to 59.8% (Table I).

The moisture content of the soil of a pond-bed (spot 4) at 30 cm. depth and that of the surrounding level ground, nearly at the same depth, was determined at different times of the year and it was found that the former soil had much more water content at any time than the latter (Text-Fig. 2). This may not only be entirely due to good retaining property of the former but also on account of accumulated water remaining on the surface for quite a long time.



TEXT-FIG. 2. Moisture contents of soil at different dates.

The permanent wilting percentage of the soils of three ponds (Nos. 1, 2 and 4) and one from the surrounding level ground near the 4th pond was determined and the result is shown below:—

Spot No.	Permanent wilting percentage
1	19.4
2	20.8
4	22.2
Level ground near spot 4	18.6

The value for the soils of pond-bed is a little higher than that of the level ground, but all the same, it is of little significance.

Chemical Characteristics

(f) *Soil reaction*.—The soils in general (except those of spots 3, 16 and 17) show a distinct basic reaction. The pH values range between 6.60 and 8.64 at a depth of 10 cm. (Table I).

(g) *Exchangeable calcium*.—These soils, being rich in clay content and poor in drainage, gain in base status as the overlying water evaporates. Percentage of exchangeable calcium, calculated as calcium oxide, varies from 0.42 to 5.13 (Table I). Thus even the minimum value is quite high when compared with those of drained soils. However, in the depressions the exchangeable iron does not seem to be as high as reported for upland areas by other workers (Bhatia, 1955).

(h) *Total soluble phosphate and nitrate*.—The total soluble phosphate also is in appreciable quantity. Nitrates of the soils did not show any significant difference from that of the upland areas (Saksena, 1955). The values range from traces to 60 parts per million (Table I).

(i) *Total soluble salts*.—Total soluble salts were also determined in all the soils but it could not be found to be markedly different. This value ranged from 40 mg. to 151 mg. per 100 gm. of dry soil (Table I).

(j) *Organic content*.—The organic content in some soils was found to be as low as 1.02% and the highest value was 4.94%, which is not very common (Table I).

Characteristics of Soil Profile

The study of soil profile at ponds 1–4 was undertaken in order to find the soil characteristics at different depths. The structure of the profile is given in Tables II and III. The data of various analyses are given in Table III. The following points are brought out by its perusal.

TABLE II

Structure of soil profile

No. of spot	Depth of horizon (in cm.)	Morphological feature
1	1-20	Black clayey soil
	21-60	Blackish grey with specks of chalk here and there. Clayey.
	61-120	Yellowish with frequent chalk specks.
	121-150	Full of chalk comparable to 'kankar'.
	151 and deeper	Could not be dug.
2	1-30	Black clayey soil.
	31-65	Greyish black with specks of chalk.
	66-145	Weathered parent rock, with some soil in between stones.
	146 and below	Parent rock, basalt.
3	1-20	Black clayey soil.
	21-80	Black clayey soil with specks of chalk.
	81-120	Yellow 'murram'-like stratum.
	121 and below	Could not be dug.
4	1-40	Black clayey soil.
	41-77	Black clayey soil with specks of chalk here and there.
	78 and below	Parent rock (basalt).

(a) *Physical characteristics*.—The clay fraction is maximum at the top horizon and gradually decreases in deeper layers, though sometimes not with strict regularity. A total of silt and clay follows the same pattern of distribution, but gravel and sand are distributed just in the opposite way—more being at the lower horizon and lesser at the top (Table III).

Carbonate content goes on increasing in deeper horizons till it reaches a maximum, after which it falls in proportion. The depth at which the maximum amount of carbonate gets deposited varies with different ponds but in majority of them it was at 75-90 cm. However,

in case of pond No. 1 it was at a depth of 150 cm. The carbonate deposition in lower horizon is due to precipitation from soluble bicarbonates. The latter are caused by water-logged conditions and these get leached to lower horizons, where they get deposited back as carbonates.

Total soluble salts are, in most cases, more at the top and less at the lower horizons.

(b) *Chemical characteristics*.—The pH at the lower horizons goes on increasing. Soluble phosphate increases with depth and so does exchangeable sesquioxide, to a certain maximum, after which there is a decline in its amount. Exchangeable calcium also goes on increasing with depth till it reaches the highest value, after which it decreases in some cases. The concentration of magnesium follows a bit erratic sequence but, in most cases, it is found to decrease at lower depth. Exchangeable potassium has a tendency to become lesser and lesser at lower horizons.

Organic matter does not show any marked trend of distribution. The maximum content is almost, in all cases, at mid-horizons. The Ao horizon of litters is unknown in these soils. Nevertheless, the lower horizons have quite low amount of organic matter.

This study brings out the fact that for this type of soil the terms A, B and C horizons cannot be used strictly in the sense used for terrestrial soils. This has also been found the case in most tropical soils (Robinson, 1949). Consequently, it can be said to have only an artificial profile because "flooding accompanied by deposition of silt from flood-water builds up only an artificial profile" (Robinson, 1949). There are several examples of large expanse of soils with artificial profile. The warp soils round the Humber estuary in England and soil built up from Nile alluvium in Egypt are among the common examples.

BIOTIC FACTORS

The biotic factors operating in the area can be said to be of two types: (i) the disturbances to the soil beds by human agencies, involving digging of the soil for multiple purposes. This operation changes the character of the top soil and also removes a crop of seeds along with the soil. (ii) Grazing by cattle is the other type. During the dry months of the summer, when the neighbouring level grounds present a pale and dreary appearance the moister beds of ponds look green with profuse growth of plants like *Heliotropium supinum* Linn., *Polygonum plebejum* Br. var. *griffithi*, *Crypsis aculeata* (L.) Cut., *Mollugo lotoides* O.Kze., *Trigonella occulta* Debile, etc. (Plate III). Most of these plants are eaten by cattle but *Crypsis aculeata* is greedily nipped. The grazing in some cases is very severe so that some plants do not get a chance to produce seeds. However, the prostrate and mat-forming plants of the pond-beds remain, to a considerable degree, immune from the teeth of the grazing animal.

TABLE
Characteristics

Spot No.	Date of collection	Depth in cm.	pH	Carbo- nate content (%)	Total soluble salts mgm. per 100 gm.	Moisture content (%)	Maximum water- holding capacity (%)	Soluble phosphate parts per million
1	20-1-1955	2-5	7.05	0.5	80.0	12.9	49.5	31.0
	"	14-20	7.45	3.9	60.0	22.7	59.8	46.5
	"	35-40	7.25	5.3	60.0	30.7	58.1	62.0
	"	87-92	7.65	12.0	70.0	32.1	56.4	77.5
	"	125-130	8.35	23.0	60.0	26.4	51.9	108.5
	"	150-155	8.35	40.0	90.0	24.2	40.9	15.5
2	8-2-1955	2-5	7.85	8.5	240.0	41.6	56.7	15.5
	"	17-20	7.45	9.5	170.0	35.8	50.9	15.5
	"	35-40	7.95	14.0	110.0	27.9	43.2	15.5
	"	87-92	8.35	27.0	65.0	10.5	31.5	15.5
	"	125-130	7.95	8.0	80.0	26.1	43.7	31.0
3	19-2-1955	2-5	6.95	1.3	77.0	27.7	42.0	31.0
	"	17-20	6.85	1.8	67.0	28.1	46.2	46.4
	"	35-40	7.55	2.7	99.0	25.9	43.4	46.4
	"	70-75	8.15	6.8	70.0	27.7	45.3	46.4
	"	80-85	8.25	4.8	62.0	21.5	36.8	46.4
4	20-2-1955	2-5	6.15	1.0	194.0	34.9	54.5	73.0
	"	17-20	6.25	0.8	151.0	36.3	54.8	46.4
	"	35-40	6.35	0.3	139.0	33.4	51.3	90.3
	"	70-75	6.90	1.7	124.0	30.3	49.6	60.2

III

of soil profile*

Exch. sesqui- oxide mgm. per 100 gm.	Exch. calcium (%)	Exch. magne- sium mgm. per 100 gm.	Exch. potas- sium mgm. per 100 gm.	Organic matter (%)	Gravel (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Silt + clay (%)
8.0	1.2	71.1	244.8	1.4	0.34	0.62	1.29	46.46	51.39	97.85
12.0	2.4	239.0	226.2	2.38	1.61	1.03	0.94	43.17	53.25	96.42
56.0	2.8	420.4	198.0	1.2	3.06	0.30	0.61	41.72	54.31	96.02
80.0	2.7	583.4	235.6	1.61	7.24	1.33	6.27	28.16	57.00	85.16
336.0	4.2	521.9	233.7	1.13	3.54	1.40	3.36	47.50	44.20	91.70
108.0	6.8	520.9	344.8	1.12	3.69	2.01	3.71	49.09	41.50	90.59
84.0	4.8	181.1	114.2	4.61	0.00	0.60	6.19	60.25	32.96	93.21
108.0	4.0	173.9	138.8	3.52	0.11	1.77	8.15	48.70	41.28	89.98
284.0	4.7	128.2	135.3	5.18	5.07	8.00	5.38	45.15	36.41	81.56
144.0	6.4	49.5	102.7	3.00	29.95	10.57	7.24	34.95	17.30	52.25
72.0	2.7	8.23	76.9	1.58	32.53	5.00	6.02	49.35	7.10	56.45
144.0	0.76	181.1	17.0	2.08	0.00	0.55	1.09	40.60	58.30	98.90
108.0	0.77	170.7	Traces	3.93	0.49	0.73	2.71	37.30	58.77	96.07
284.0	1.18	128.2	39.8	3.38	1.90	1.14	3.32	35.65	57.99	93.64
144.0	3.08	49.4	Traces	2.29	7.22	2.48	3.90	31.15	55.25	86.40
72.0	1.85	8.23	17.0	0.66	39.53	31.50	5.01	8.25	15.71	23.96
486.0	0.51	293.4	114.0	3.00	0.00	0.11	0.90	39.69	59.30	98.99
286.0	0.49	176.0	34.0	3.59	0.00	0.09	1.72	41.75	56.45	98.20
170.0	0.54	172.9	31.2	2.59	0.16	0.48	1.17	39.49	58.70	98.19
118.0	1.00	236.4	17.0	2.17	2.29	1.57	4.31	39.83	52.01	91.84

* Results are based on an average of two determinations.

Humble bees flock to the colonies of *Polygonum plebejum* during its flowering stage, thus helping pollination of the species.

The Structural Characteristics of the Community

The spots 1 to 4 are somewhat bigger ponds as compared to the rest and hence vegetation types at these spots are described separately and those of the other fifteen spots are dealt with together. Only the flowering plants have been taken into account. Other vascular plants were absent except *Marsilea quadrifolia*, which was present only at spot 1, and that too during the early stages of its drying.

(A) *The Vegetation Types at Spot 1*

Type (i) *Crypsis aculeata*-*Gnaphalium pulvinatum*

Species	F.	d.	A.	D.
1. <i>Crypsis aculeata</i> ..	5	97	5	5
2. <i>Gnaphalium pulvinatum</i> ..	5	47	4	4
3. <i>Polygonum plebejum</i> ..	5	19	2	2
4. <i>Heliotropium supinum</i> ..	5	10	1	1
5. <i>Trigonella occulta</i> ..	5	6	1	1

Total cover = 95%

This type was found on the soil at the deepest part of the pond, where water disappears last.

Type (ii) *Trigonella occulta*-*Polygonum plebejum*

Species	F.	d.	A.	D.
1. <i>Trigonella occulta</i>	5	176	5	5
2. <i>Polygonum plebejum</i>	5	26	3	3
3. <i>Gnaphalium pulvinatum</i> ..	5	4	1	2
4. <i>Crypsis aculeata</i>	5	2	1	1

Total cover = 98%

This type was in areas slightly shallower than A (i). This was wholly dominated by *Trigonella occulta* but *Crypsis aculeata*, a dominant of A (i), was very much reduced in its abundance.

Type (iii) *Polygonum plebejum*-*Crypsis aculeata*

	Species	F.	d.	A.	D.
1.	<i>Polygonum plebejum</i> ..	5	73	5	4
2.	<i>Crypsis aculeata</i> ..	5	21	3	2
3.	<i>Gnaphalium pulvinatum</i> ..	5	13	2	2
4.	<i>Trigonella occulta</i> ..	5	7	1	1
5.	<i>Sutera glandulosa</i> Roth. ..	5	3	1	1
6.	<i>Polypogon monspeliensis</i> Dorf. ..	2	7	1	1
7.	<i>Caesulia axillaris</i> Roxb. ..	3	2	1	1
8.	<i>Potentilla supina</i> L. ..	2	3	1	1
9.	<i>Cochlearia flava</i> Buch. Ham. ..	2	2	1	1
10.	<i>Rumex dentatus</i> Linn. ..	2	3	1	1

Total cover = 75%

F. = Frequency Class; d. = Density (Oosting, 1956);

A. = Abundance Class; D. = Dominance Class.

This type was found towards the margins, wherefrom water recedes first, enabling these plants to take a start in life earlier than those at the bottom of the pond.

(B) *Vegetation Types at Spot 2*

This pond was the biggest of all the four and presented greater variation in floristic compositions.

Type (i) *Crypsis aculeata*-*Polygonum plebejum*

	Species	F.	d.	A.	D.
1.	<i>Crypsis aculeata</i> ..	5	97	5	5
2.	<i>Polygonum plebejum</i> ..	5	43	5	4
3.	<i>Mollugo lotoides</i> ..	5	21	3	2
4.	<i>Gnaphalium pulvinatum</i> ..	5	5	1	1
5.	<i>Argemone mexicana</i> Linn. ..	4	1	1	1
6.	<i>Trigonella occulta</i> ..	3	Less than 1	1	1
7.	<i>Xanthium strumarium</i> Linn. ..	2	„	1	1

Total cover = 98%

This type is characteristic of the deeper part which remains fully exposed to sun during all the day time. Just like the first spot here also, the bottom of exposed parts is dominated by *Crypsis aculeata*.

Type (ii) *Argemone mexicana*-*Crypsis aculeata*

Species	F.	d.	A.	D.
1. <i>Argemone mexicana</i>	5	53	5	5
2. <i>Crypsis aculeata</i>	5	31	5	4
3. <i>Mollugo lotoides</i>	5	23	4	3
4. <i>Althaea ludwigii</i> Linn. ..	4	5	2	1
5. <i>Polygonum plebejum</i>	5	7	2	2
6. <i>Heliotropium supinum</i> ..	4	1	1	1

Total cover = 90%

This type was growing on shallower parts near eastern margin of the pond. There was some shade for part of the day due to a big tree of *Ficus religiosa* Linn.

Type (iii) *Crypsis aculeata*-*Mollugo lotoides*-*Gnaphalium pulvinatum*

Species	F.	d.	A.	D.
1. <i>Crypsis aculeata</i>	5	51	5	5
2. <i>Gnaphalium pulvinatum</i> ..	5	35	5	3
3. <i>Mollugo lotoides</i>	5	29	5	4
4. <i>Argemone mexicana</i>	3	4	2	1
5. <i>Eclipta erecta</i> Linn. ..	1	1	1	1

Total cover = 95%

This type was found towards the western margin on shallower parts. The area was under the shade of big trees of *Pongamia pinnata* (Linn.) Pierre and *Terminalia glabra* W. and A., which produce shade for the area for some hours of the day.

Type (iv) *Mollugo lotoides*-*Crypsis aculeata*

Species	F.	d.	A.	D.
1. <i>Mollugo lotoides</i>	5	43	5	4
2. <i>Crypsis aculeata</i>	5	35	5	4
3. <i>Heliotropium supinum</i> ..	5	13	3	3
4. <i>Polygonum plebejum</i>	5	6	2	2
5. <i>Argemone mexicana</i>	3	Less than 1	1	1

Total cover = 90%

This type is characteristic of western side, which is exposed to sunshine for all the day.

(C) The Analysis of Vegetation of Spot 3

Type (i) *Argemone mexicana*-*Polygonum plebejum*

Species	F.	d.	A.	D.
1. <i>Argemone mexicana</i>	5	85	5	5
2. <i>Polygonum plebejum</i>	5	49	5	4
3. <i>Heliotropium supinum</i>	5	4	1	1
4. <i>Trigonella occulta</i>	2	Less than 1	1	1
5. <i>Gnaphalium pulvinatum</i>	3	4	1	1
6. <i>Sutera glandulosa</i>	2	1	1	1
7. <i>Chrozophora prostrata</i> Dalz.	1	Less than 1	1	1
8. <i>Mollugo lotoides</i>	1	„	1	1
9. <i>Lathyrus</i> sp.	1	„	1	1

Total cover = 85%

This type of vegetation was found at the deepest part of the pond. *Argemone mexicana* was dominating.

Type (ii) *Heliotropium supinum*-*Argemone mexicana*-*Polygonum plebejum*

Species	F.	d.	A.	D.
1. <i>Heliotropium supinum</i>	5	55	5	4
2. <i>Argemone mexicana</i>	5	34	5	3
3. <i>Polygonum plebejum</i>	5	30	5	3
4. <i>Gnaphalium pulvinatum</i>	4	2	1	1
5. <i>Mollugo lotoides</i>	4	2	1	1
6. <i>Volutarella divaricata</i> Benth. and Hook.	3	1	1	1
7. <i>Sutera glandulosa</i>	3	1	1	1
8. <i>Trigonella occulta</i>	1	1	1	1

Total cover = 70%

This type was represented towards the margin of northern shallower parts. *Heliotropium supinum* was very conspicuous.

(D) The Vegetation on Spot 4

Type (i) *Polygonum plebejum*-*Heliotropium supinum*

	Species	F.	d.	A.	D.
1.	<i>Polygonum plebejum</i> ..	5	5	5	2
2.	<i>Heliotropium supinum</i> ..	2	Less than 1	3	1
3.	<i>Gnaphalium pulvinatum</i> ..	1	„	3	1

Total cover = 20%

This type was found at the deepest part of the pond, where the soil and subsoil together were only 46 cm. in depth, overlying the parent rock (basalt). This is a representative of the poorest cover on the bed of a pond. The plants in this portion of the pond were ill-developed. This may be due to a thinner layer of soil, which loses its water sooner than the other soils.

Type (ii) *Chrozophora rottleri*-*Heliotropium supinum*

	Species	F.	d.	A.	D.
1.	<i>Chrozophora rottleri</i> A. Juss. ..	5	41	5	4
2.	<i>Heliotropium supinum</i> ..	4	5	3	2
3.	<i>Polygonum plebejum</i> ..	4	5	3	2
4.	<i>Chrozophora prostrata</i> ..	3	2	2	1
5.	<i>Gnaphalium pulvinatum</i> ..	3	1	1	1

Total cover = 60%

This type was found on shallower parts, where soil and subsoil was 76 cm. deep. Apart from the above species, which were found on the bottom of the pond, there were plants of *Caesulia axillaris*, *Eclipta erecta* and *Alternanthera sessilis* R.Br., growing on the sides of the pond.

Synthetic Characters of the Vegetation of the Four Ponds

Fidelity.—The fidelity of the various species of the community was determined as suggested by Braun-Blauquet *et al.* (1932). The total number of species growing on beds of these ponds is quite small and with regard to this habitat, some species could be recognised as exclusive ones and others could be placed in different degrees of fidelity, as shown in Table IV.

A perusal of Table IV indicates that species 1 to 12 are characteristic ones for the community and habitat, as they fall under fidelity class 5 and 4 (Oosting, 1956).

TABLE IV
Fidelity of various species

Fidelity class	Species	In the community of the pond-beds		In other communities occurring in the neighbouring areas	
		Pre-sence class	Abundance class	Pre-sence class	Abundance class
5.	1. <i>Heliotropium supinum</i>	5	5	Absent	Nil
	2. <i>Mollugo lotoides</i>	5	5	"	"
	3. <i>Gnaphalium pulvinatum</i>	5	4	"	"
	4. <i>Crypsis aculeata</i>	4	5	"	"
	5. <i>Trigonella occulta</i>	4	3	"	"
	6. <i>Polygonum plebejum</i>	5	5	1	1
	7. <i>Cochlearia flava</i>	1	1	Absent	Nil
	8. <i>Chrozophora prostrata</i>	2	1	"	"
	9. <i>Althaea ludwigii</i>	1	1	"	"
	10. <i>Polypogon monospeiensis</i>	1	1	"	"
4	11. <i>Sutera glandulosa</i>	3	2	1	1
	12. <i>Argemone mexicana</i>	4	2	1	1
2	13. <i>Potentilla supina</i> L.	2	1	1	1
	14. <i>Chrozophora rottleri</i>	1	1	1	1

(E) *Vegetation Types of Spots 5-19*

The vegetation of all the roadside depressions (spots 5-19) has been taken together due to almost identical habitat in all the cases and represented in Table V. These depressions dry up earlier than the larger ponds of spots 1-4. The community starts its life earlier, and the plants dry up sooner. With regard to their soil conditions they cannot be said to be much different from those of the bigger ponds.

TABLE V

Phytosociological characters of vegetation on spots 5-19

	Species	F.	d.	A.	D.
1.	<i>Heliotropium supinum</i>	.. 5	16	3	3
2.	<i>Polygonum plebejum</i>	.. 5	12	3	3
3.	<i>Chrozophora prostrata</i>	.. 2	4	1	1
4.	<i>Crypsis aculeata</i> ..	.. 1	1	1	1
5.	<i>Sutera glandulosa</i> ..	.. 2	1	1	1
6.	<i>Potentilla supina</i> ..	.. 1	3	1	1
7.	<i>Nasturtium indicum</i> DC.	.. 1	Less than 1	1	1
8.	<i>Scirpus michelianus</i> L.	.. 1	„	Trifling	Trifling
9.	<i>Euphorbia hypercifolia</i> Linn.	.. 2	2	1	1
10.	<i>Mollugo lotoides</i> ..	.. 1	1	Trifling	Trifling
11.	<i>Chrozophora rottleri</i>	.. 2	2	1	1
12.	<i>Gnaphalium pulvinatum</i> ..	.. 2	1	Trifling	Trifling
13.	<i>Argemone mexicana</i>	.. 2	5	2	1
14.	<i>Sphaeranthus indicus</i> L.	.. 1	1	Trifling	Trifling
15.	<i>Trigonella occulta</i> ..	.. 1	1	„	„
16.	<i>Volutarella divaricata</i>	.. 1	Less than 1	„	„
17.	<i>Merremia emarginata</i> Hallier f.	1	„	„	„
18.	<i>Xanthium strumarium</i>	.. 1	„	„	„
19.	<i>Cynodon dactylon</i> Pers.	.. 1	„	„	„
20.	<i>Caesulia axillaris</i> ..	.. 1	„	„	„
21.	<i>Asteracantha</i> sp. ..	.. 1	„	„	„
22.	<i>Cochlearia flava</i> ..	.. 1	„	„	„
23.	<i>Polanisia chelidoni</i> DC.	.. 1	„	„	„
24.	<i>Cassia tora</i> L. . . .	.. 1	„	„	„
25.	<i>Cassia obtusifolia</i> L.	.. 1	„	„	„
26.	<i>Phyllanthus</i> sp. ~ ..	.. 1	„	„	„

The fidelity of the species of spots 5-19 has been determined and given in Table VI.

TABLE VI
Fidelity of the species

Fidelity class	Species	In the community		In other communities	
		Pre-sence class	Abundance class	Pre-sence class	Abundance class
5	1. <i>Heliotropium supinum</i>	5	3	Absent	Nil
	2. <i>Polygonum plebejum</i> ..	5	3	Trifling	Trifling
	3. <i>Chrozophora prostrata</i>	2	1	Nil	Nil
	4. <i>Crypsis aculeata</i> ..	1	1	"	"
	5. <i>Gnaphalium pulvinatum</i>	2	1	"	"
	6. <i>Sphaeranthus indicus</i> ..	1	1	"	"
	7. <i>Trigonella occulta</i> ..	1	1	"	"
	8. <i>Cochlearia flava</i> ..	1	1	"	"
	9. <i>Polanisia chelidoni</i> ..	1	1	"	"
	10. <i>Scirpus michelianus</i> ..	1	1	"	"
	11. <i>Nasturtium indicum</i> ..	1	1	"	"
	12. <i>Mollugo lotoides</i> ..	1	1	"	"
	13. <i>Gnaphalium luteo-album</i>	1	1	Nil	Nil
4	14. <i>Sutera glandulosa</i> ..	2	1	1	1
	15. <i>Argemone mexicana</i> ..	2	1	1	1
	16. <i>Caesulia axillaris</i> ..	1	1	Trifling	Trifling
	17. <i>Potentilla supina</i> ..	1	1	"	"
	18. <i>Eclipta erecta</i> ..	1	1	"	"
	19. <i>Asteracantha</i> sp. ..	1	1	"	"
2	20. <i>Chrozophora rottleri</i> ..	2	1	1	1
	21. <i>Volutarella divaricata</i> ..	1	1	1	1
	22. <i>Merremia emarginata</i>	1	1	1	1
	23. <i>Xanthium strumarium</i>	1	1	1	1
	24. <i>Cynodon dactylon</i> ..	1	1	1	1
	25. <i>Euphorbia hypercifolia</i> Linn.	2	1	1	1
	26. <i>Phyllanthus</i> sp. ..	1	1	1	1

Table VI brings out 1 to 13 as exclusive and 1 to 19 as characteristic species as they fall under fidelity class 5 and 4 (Oosting, 1956). By comparing the characteristic species for this community with those of the deeper ponds it can be seen that many species are common to both and they could be truly representative species in all low-lying areas, where accumulated water does not remain permanently, but dries up in winter, whereas species 20 to 26 are indifferent.

The majority of characteristic species have prostrate form, in some cases appressed to the ground and some showing rosette forms. This habit in the plants may be due to genic factor but is also partly induced in response to intense light, to which they are exposed for all the day long, as proved by culture experiments. In these experiments *Heliotropium supinum*, *Polygonum plebejum* and *Mullugo lotoides* were grown in pots having soil of pond-beds. One set of pots was kept in a verandah, where only mild direct sunlight was available for two hours in the morning and another set was kept outside where direct sunlight was available for all the day long. Watering was done every day in both the cases to the same extent. But those kept exposed to sunlight throughout the day acquired prostrate and appressed habit in contrast to those of shade which remained erect and straggling with long internodes (Plate IV). *Trigonella occulta* also acquires erect or semi-erect form in shade.

EPIDERMAL STRUCTURE

In most of the species the leaves are covered profusely with simple or branched hairs and in many cases hairs are on the stem too. Stomatal counting was done in some characteristic species and the result is given in Table VII.

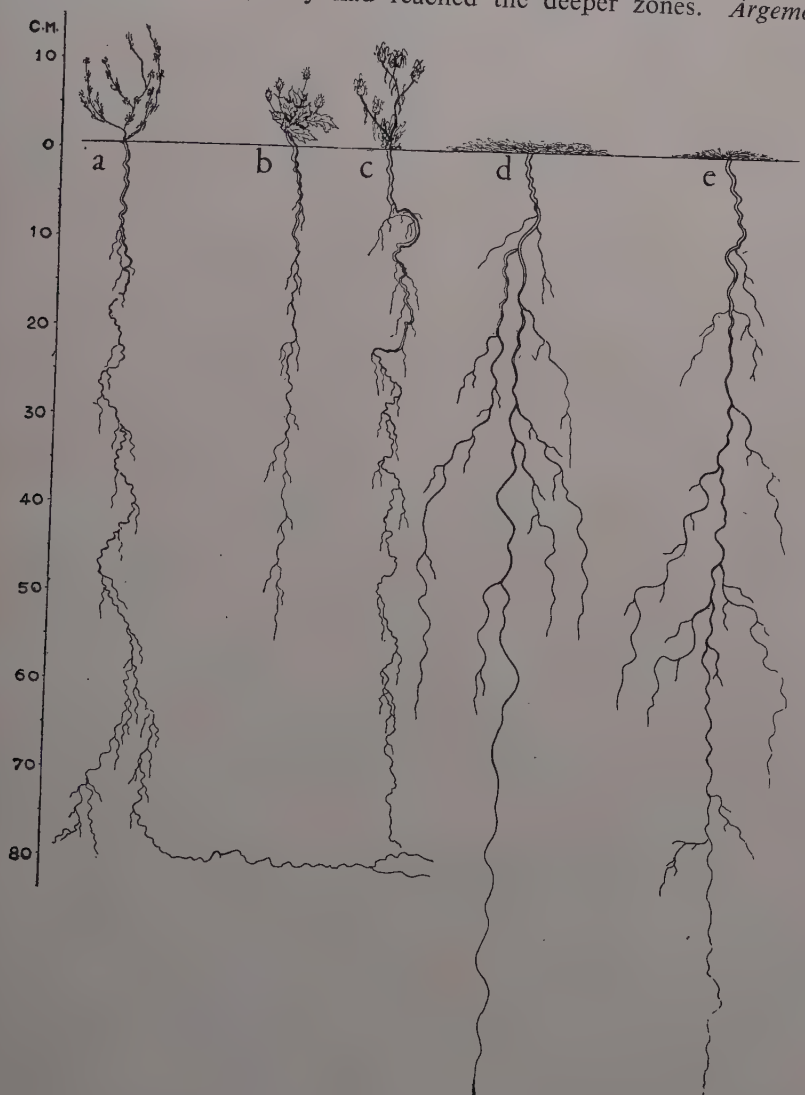
TABLE VII
Stomatal frequency

Species	Stomata per square mm.	
	Upper surface	Lower surface
<i>Mollugo lotoides</i>	65- 70	125-180
<i>Heliotropium supinum</i>	150-160	250-300
<i>Chrozophora rottleri</i>	125-130	187-200

Thus the number of stomata corresponds to that of mesophytic plants.

ROOT SYSTEM

The roots in case of *Heliotropium supinum*, *Polygonum plebejum*, *Sutera glandulosa*, *Volutarella divaricata* and *Argemone mexicana* were studied at spot 3. The root system of all these plants showed a strong tap root with only a few strong laterals (Text-Fig. 3 and Plate IV). In almost all the cases, they had reached the deeper zones. *Argemone*



TEXT-FIG. 3. Root systems.

a, *Sutera glandulosa*; b, *Argemone mexicana*; c, *Volutarella divaricata*; d, *Heliotropium supinum*; e, *Polygonum plebejum*.

mexicana seemed to have a somewhat shorter tap root, *Heliotropium supinum* and *Polygonum plebejum* have the longest, attaining a length of 1·2 m. or so. The tap roots of *Sutera glandulosa* were found to penetrate up to 85 cm., *Volutarella divaricata* up to 70 cm. and *Argemone mexicana* almost up to a similar depth. The roots in comparison to the tops were developed more extensively. At the same time roots showed very tortuous and curled appearance in almost all cases, presumably due to resistance of the heavy soil to their penetration. The roots were found to grow very fast reaching the deeper layers quite early and thus placing themselves in a stratum of the best water condition. However, it is worthy of mentioning that Bhide (1921) has recorded that plants of *Heliotropium supinum*, *Argemone mexicana*, *Chrozophora prostrata* and *Polygonum plebejum* have tap roots 15–18 cm., 23–25 cm. and 5–6 cm. respectively. These figures are too small and may be due to shallow layer of the soil. Roots in all these cases have a tendency to reach quite deep layers and even up to the parent rock if it lies at a depth of 1·2–1·5 m.

OSMOTIC CONCENTRATION

The osmotic concentration of press-sap in case of some species was determined cryoscopically at 12·0 NOON in order to correlate it with the variations in the moisture content of the soil. The result is shown in Table VIII.

A number of workers has determined fluctuations in the osmotic concentration of sap of some plants. Harris and others (1921) determined the osmotic concentration in case of two species of *Cuscuta* and the range of variations was found to be 5·36–37·00 atmosphere. Parija and Saran (1932) found that osmotic concentration of the sap of *Cuscuta reflexa* varies with that of the host but after attaining a certain maximum does not increase further, so much so, that the osmotic pressure of the host tissue may be more than that of the parasite. However, normally, the osmotic pressure of the parasite adjusts in such a manner as to be more than that of the host. Sen Gupta (1935) studied the osmotic pressure of press-sap of leaves in cases of a large number of plants, including aquatic plants like *Nymphaea* sp. where the value was only 5·904 atm., and trees like *Azadirachta indica* A. Juss., where the value was 17·92 atm.

Cooper and Pasha (1935) determined the osmotic pressure of cell sap of root, stem and leaves separately at different times of the year in case of *Acanthus ilicifolius*, *Avicennia officinalis* and *Sonneratia apetala* and found that it went on increasing with the progress of the dry season, though there was no corresponding increase in the osmotic pressure of the sea-water and they concluded, "The increase in osmotic pressure of the plants from July to October can be due to two reasons: Firstly, the greater transpiration may bring about concentration of salts which would result in an increase in the osmotic pressure. It means that the absorption of water from the soil is less than the water transpired. Secondly, the increase in osmotic pressure may be due to greater absorption of salts along with greater absorption of water as the transpiratory activity increases. The second reason given for the increase in the osmotic

pressure seems to be more acceptable than the first." However, in the case of plants under the present study it could be said that the increase of osmotic pressure of cell sap during dry months may be more due to the first cause because the chemical analysis, during the stage of maximum osmotic pressure (fruiting stage) of these plants reveals that there is the least amount of water in plant tissue and also the mineral contents are lesser as compared to those during flowering and pre-flowering stages. As these plants develop maximum osmotic pressure when there is least amount of moisture in the soil, they must be in a better position to absorb water from the soil, which is poor in water content.

TABLE VIII

Soil moisture and osmotic pressure of cell sap

Moisture content of soil at 10 cm. depth (%)	Osmotic pressure in atmosphere				
	<i>Helio- tropium supinum</i>	<i>Mollugo lotoides</i>	<i>Gnapha- lium pulvi- natum</i>	<i>Chroz- ophora prostrata</i>	<i>Argemone mexicana</i>
40.2	8.0	..	..	..	..
35.2	11.6	9.7	10.5	..	10.8
31.6	10.6	8.5	..	16.6	15.5
8.0	23.6	22.4	23.1	28.1	20.3

The above observations bring out the facts that the seeds of these plants start germination (Plate III) with the drying of the ponds and depressions, which normally happens from October onwards to January. Flowering starts after vegetative growth of nearly two months or a little less. In culture experiments it was found that *Polygonum plebejum* if sown earlier flowered even as early as beginning of October—a time when seeds get a chance to germinate in shallower depressions. *Heliotropium supinum* produced a very limited number of flowers when grown in a verandah, where it received direct light only for two hours in the mornings and for the rest of the day got only diffused light. It seems that in cases where plants are watered every day the flowering is delayed by nearly a week and plants survive till April, the time coinciding with that in nature. Watering at longer intervals forces the plants to complete their life-cycle earlier.

Thus the vegetation of low-lying areas is quite characteristic and consists of annuals only. Some of the component species can be described as exclusive species and some as constant species.

SUMMARY

1. Soil and vegetation characteristics of 19 temporary pools and depressions in Saugor and neighbouring areas have been described. This vegetation consists of annuals only. Nineteen species have been considered as characteristic ones for the habitat.

2. Root systems of five species have been studied. In all these cases there is a strong tap root with a few weak laterals.

3. The stomatal frequency of some species has been calculated.

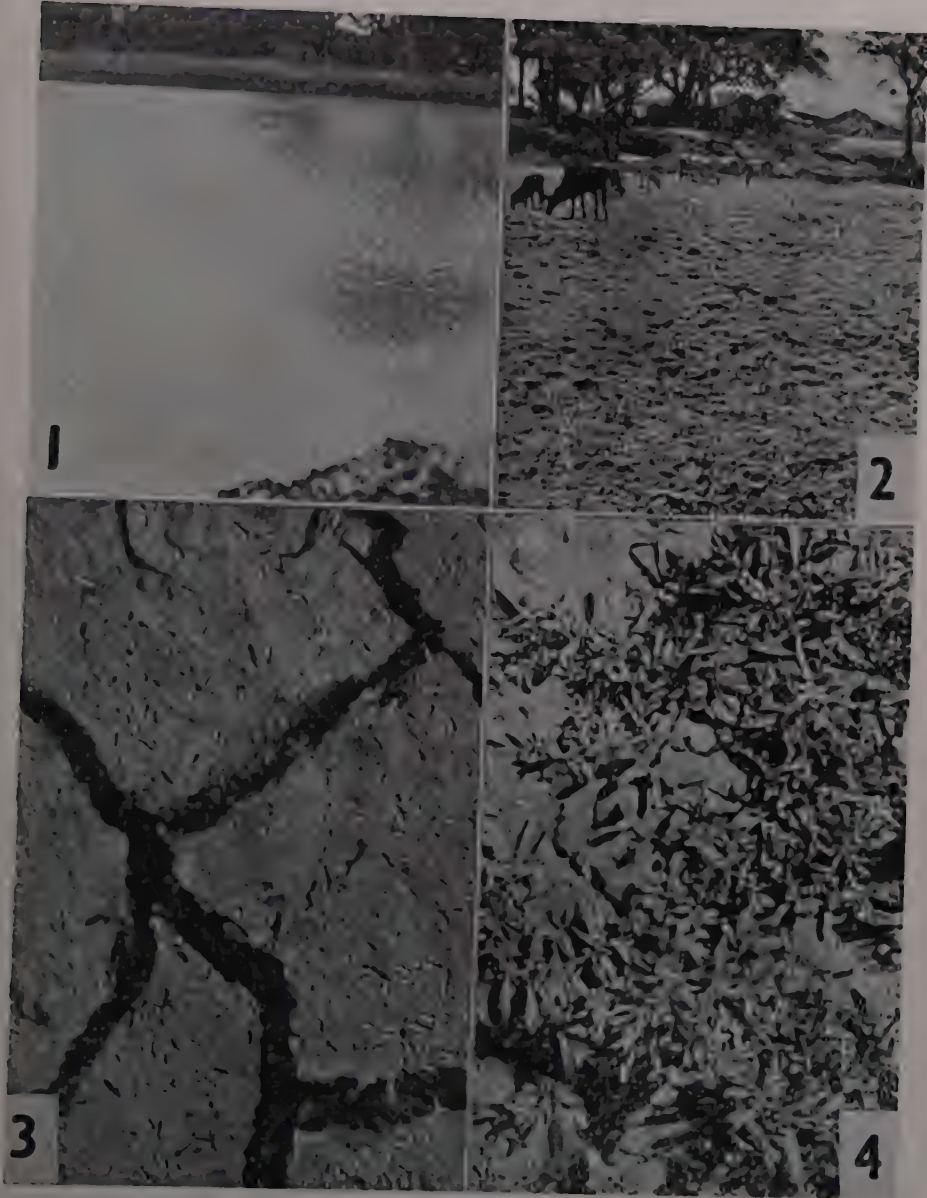
4. Change of osmotic concentrations of cell sap of five species in response to varying moisture contents of soil has been investigated.

ACKNOWLEDGEMENT

The writer wishes to express his great indebtedness to Prof. R. Misra. Head of the Department of Botany, Banaras Hindu University, for his constant help and guidance during the course of this investigation.

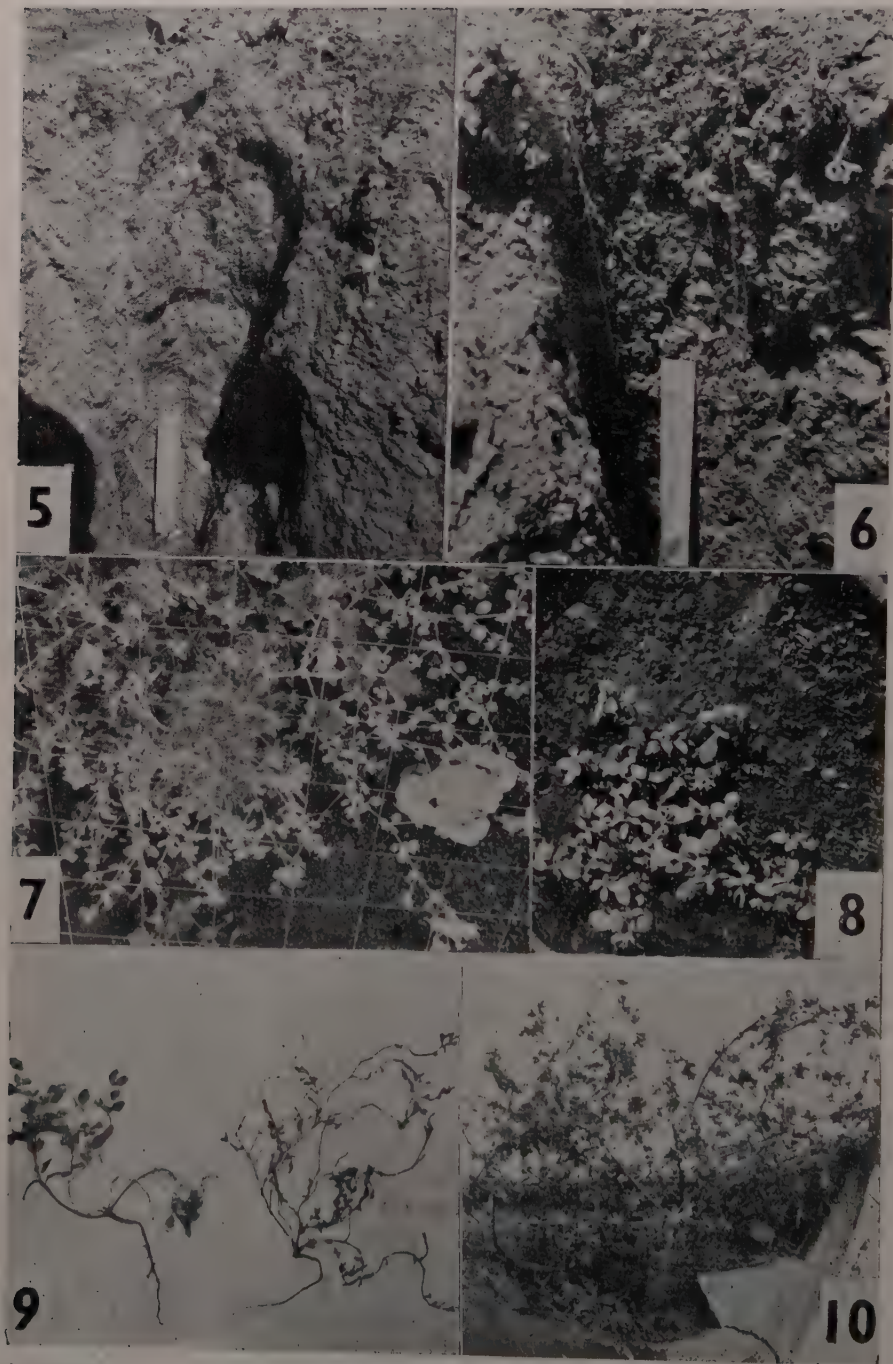
REFERENCES

- BHATIA, K. K. 1955. Foliar calcium of teak. *J. Indian bot. Soc.* **34**: 227-34.
- BHIDE, R. K. 1921. Drought resisting plants in Deccan. *Ibid.* **2**: 27-43.
- BRAUN-BLAUQUET, J., FULLER, G. D. AND CONARD, H. S. 1932. *Plant Sociology*. McGraw-Hill Book Company, Inc., New York and London, 439 pp.
- COOPER, R. E. AND PASHA, S. A. 1935. The osmotic and suction pressures of some species of mangrove vegetation. *J. Indian bot. Soc.* **14**: 109-20.
- DAUBENMIRE, R. F. 1942. An ecological study of the vegetation of South Eastern Washington adjacent Idaho. *Ecol. Monog.* **12**: 56-79.
- . 1947. *Plants and Environment*. John Wiley and Sons, Inc., New York.
- DUDGEON, W. 1920. A contribution to the ecology of the Upper Gangetic Plain. *J. Indian bot. Soc.* **1**: 296-324.
- HALL, A. D. AND ROBINSON, G. W. 1945. *The Soil*. John Murray, pp. 322.
- HARRIS, J. A. *et al.* 1921. Maximum values of osmotic concentration in plant fluids. *Proc. Soc. Exper. and Med.* **18**. (Cited from Parija & Saran 1932).
- KASSAS, M. AND IMAM, M. 1954. Habitat and plant communities in the Egyptian desert III. The wadi bed ecosystem. *Ecology*, **42**: 424-41.
- MICHELMORE, A. P. G. 1939. Observations on Tropical African grasslands. *J. Ecol.* **27**: 282-312.
- MISRA, R. 1946. A study in the ecology of low-lying land. *Indian Ecologist* **1**: 1-20.
- OOSTING, H. J. 1956. *Plant Communities*. W. H. Freeman and Company. San Francisco.
- PARIJA, P. AND SARAN, A. B. 1932. Variability of the osmotic strength of the sap of *Cuscuta reflexa* Roxb. *J. Indian bot. Soc.* **11**: 271-75.
- PIPER, C. S. 1944. *Soil and Plant Analysis*. The Univ. of Adelaide, Adelaide.



L. P. Mall

FIGS. 1-4



- POLUNIN, N. 1934. The vegetation of Akpatok Islands, Part I. *J. Ecol.* **22**: 337-95.
 ———, 1935. The vegetation of Akpatok Islands, Part II. *Ibid.* 161-209.
 RATNAM, B. V. AND JOSHI, M. C. 1952. An ecological study of the vegetation near about a temporary pond in Pilani. *Proc. Raj. Acad. Sci.* **3**: 1-15.
 REA, M. W. 1921. Stomata and hydathodes of *Campanula rotundifolia* and their relation to environment. *New Phytol.* **20**: 56-72.
 ROBINSON, G. W. 1949. *Soils—Their Origin, Constitution and Classification*. Thomas Murby & Co., London, pp. 573.
 SAKSENA, S. B. 1955. Ecological factors governing the distribution of soil micro-fungi in some forest soils of Saugar. *J. Indian bot. Soc.* **34**: 262-98.
 SEN GUPTA, J. C. 1935. On the osmotic value relations of our plants II. *Proc. 22nd Indian Sci. Cong.*, p. 276.

EXPLANATION OF PLATES III AND IV

PLATE III

- FIG. 1. Second pond (spot 2) full of water in August 1954.
 FIG. 2. Same, when completely dry in April 1955.
 FIG. 3. Bed of second pond soon after drying.
 FIG. 4. Same, a little later.

Seedlings and grown-up plants of *Crypsis aculeata*, *Polygonum plebejum* and *Gnaphalium pulvinatum* are seen in Figs. 3 and 4.

PLATE IV

- FIG. 5. Root systems of *Heliotropium supinum* and *Polygonum plebejum*.
 FIG. 6. Same of *Sutera glandulosa* and *Argemone mexicana*. A foot-scale is placed vertically in Figs. 5 and 6.
 FIG. 7. Bed of fourth pond, showing *Chrozophora rottleri* (with large leaves), *Mollugo lotoides* (with elongated, prostrate stem) and *Heliotropium supinum*.
 FIG. 8. Pot with *Heliotropium supinum* (with large leaves) grown in the open showing habit.
 FIG. 9. Specimens of *Heliotropium supinum* (left) and *Polygonum plebejum* removed from culture pots, where received direct light only for two hours in the morning during the experimental period.
 FIG. 10. *Mollugo lotoides*, grown in a pot and getting direct sunlight only for two hours in the morning.

Plants of *Heliotropium supinum*, *Polygonum plebejum* and *Mollugo lotoides* shown in Figs. 9 and 10 show a deviation from their normal habit.

STUDIES IN POLYPODIACEAE

VII. *Pyrrosia*

BY B. K. NAYAR

Botany Laboratories, National Botanic Gardens, Lucknow

(Received for publication on October 27, 1959)

Pyrrosia Mirbel (*Cyclophorus* Desv., *Niphobolus* Kaulf.) is a genus of small epiphytic tropical ferns, with about 100 species in S.-E. Asia, ranging from New Zealand to Siberia and from Africa to Polynesia. The present study attempts a phylogenetic evaluation of the morphology of the sporophytes and gametophytes of *P. adnascens* (Sw.) Ching, *P. fissa* (Don) Ching, *P. beddomeana* (Gies.) Ching, *P. flocculosa* (Don) C. Chr., *P. lanceolata* (L.) Alston, *P. heteractis* (Mett.) C. Chr. and *P. varia* (K.) Farwell. All the species (except *P. beddomeana*, which is from the Western Ghats of Southern India) were collected from N.-E. India, mainly from the Khasi and Jaintia Hills of Assam. Anatomy of the sporophyte is studied mainly from free-hand sections of fresh material, stained with safranin and fast green. For study of the gametophyte, the same methods were employed as described earlier (Nayar, 1960). Gametophytes collected from nature were used for comparison. Spore studies are based on mounts of acetolysed spores (Erdtman, 1952). The colour of the spores wherever mentioned refer to fresh, mature spores. Spore measurements are exclusive of excrescences.

RHIZOME

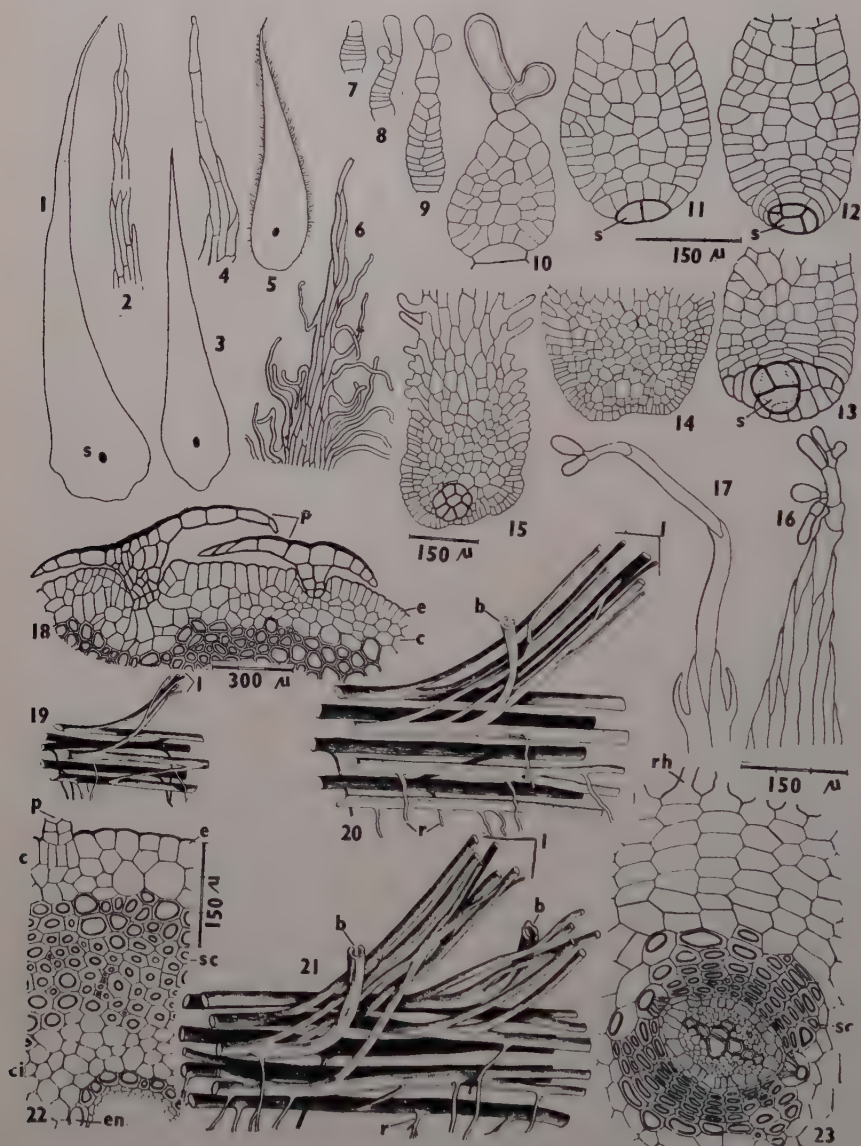
The rhizome is creeping, branched and clothed by peltate paleae with acuminate, recurved tips. In *P. adnascens*, *P. lanceolata*, *P. heteractis* and *P. varia* it is slender (c. 2.0 mm. in diameter), hard, long and wide-creeping, clinging to the substratum by wiry, black, highly branched roots with persistent root-hairs. The leaves are sparsely arranged and the branches bear no relation to them. In *P. beddomeana*, *P. fissa* and *P. flocculosa* the rhizome is fleshy, short and thick (c. 10 mm. in diameter), covered on the upper surface by closely set, persistent leaf bases and on the lower by clusters of black, thin, highly branched roots forming spongy masses. The leaves are crowded and each is associated with a lateral adventitious bud, which generally remains dormant. Paleae occur interspersed between leaf bases and roots. Gross morphology of the mature paleae is as described by Giesenhagen (1901). Mature paleae are peltate, with a broad basal region and gradually tapering apex. The margin of the paleae varies from entire as in *P. flocculosa* (Text-Figs. 1, 2) and *P. fissa* (Text-Figs. 3, 4) to hairy as in *P. adnascens* (Text-Figs. 5, 6). Each palea terminates apically in a branched or unbranched, ovate or club-shaped cell with dense contents

and probably glandular in very young paleae (Text-Figs. 16, 17). Pandé (1935) reported occurrence of stellate hairs (of the type found on leaves) on the rhizome, mixed with the paleae, in *P. adnascens*. In the present studies, however, hairs were not observed on the rhizome in any species. The stalk of the palea is 4 to 5 cells thick, deep-brown and immersed in a small depression interrupting the epidermis of the rhizome (Text-Fig. 18): the base is capable of absorbing water. Fresh, rootless but leaf-bearing regions of the rhizome of *P. varia*, *P. adnascens* and *P. lanceolata* immersed in a dilute solution of neutral red, show the dye penetrating to the cortex through the basal regions of the paleae, the remaining regions beneath the epidermis being devoid of any colouration.

Each palea originates as a uniseriate multicellular hair (Text-Fig. 7) in which the terminal cell soon becomes enlarged and culb-shaped with dense granular contents (Text-Fig. 8). Cells of the posterior end of the hair, other than the basal cell which later forms the stalk of the palea, divide longitudinally bringing about broadening (Text-Fig. 9). Successive longitudinal and transverse divisions result in the expansion of the palea into an oval structure (Text-Figs. 10, 11). Cells abutting on the stalk protrude on the surface away from the rhizome and the protrusions are later cut off as a hood over the stalk (Text-Figs. 12, 13). The hood expands (Text-Figs. 13–15) to form the posterior region of the mature palea, making it peltate. Meanwhile the single stalk cell by anticlinal and periclinal divisions (Text-Figs. 10–13) forms a short, cylindrical, multicellular stalk.

Structurally, the rhizome of the species with thin, wide-creeping rhizomes resembles that of *Drymoglossum* (Nayar, 1957). The ground tissue is parenchymatous with prominent air spaces. There is a well marked sclerenchyma sheath composed of 4–10 layers of highly thick-walled cells separating the outer cortex (3–5 layers of cells) from the inner (Text-Fig. 22). The sclerenchyma sheath is three to five cells thick and the cells have brown, lamellated walls. Species with short thick rhizomes differ in having larger parenchyma cells with less prominent intercellular spaces and dense starch contents. Usually a few of the central cells of the pith, in older regions of the rhizome, possess dark deposits and may have thickened walls. The vascular system is a highly dissected siphonostele (“false dictyostele”) with the individual strands arranged in the form of a cylinder. The young rhizome is protostelic and gradually passes on to the adult condition as described for *Pseudodrynaria* (Nayar, 1954). Other structural details of the rhizome are as described by Giesenhausen.

Leaf traces originate from the vascular bundles on the dorsal side of the rhizome. In species with long, thin rhizomes, the branch traces are formed irregularly and do not bear any relation to the leaf traces. Early juvenile leaves formed on the protostelic rhizome have a single vascular strand, forming the leaf trace. Later, as the size of the lamina increases and the vascular system of the rhizome becomes a dissected siphonostele, two strands (one originating from the median vascular bundle of the rhizome and the other from a bundle next to it) supply each leaf. In adult plants the dorsal median bundle of the rhizome



TEXT-FIGS. 1-23. Morphology of the paleae, rhizome and root.

Fig. 1. Palea of *P. flocculosa*. Fig. 2. Tip of the same, showing details. Fig. 3. Palea of *P. fissa*. Fig. 4. Tip of the same, showing details. Fig. 5. Palea of *P. adnascens*. Fig. 6. Tip of the same, showing details. Figs. 7-15. Stages in the development of the paleae in *P. varia*. Figs. 16, 17. Tips of young paleae of *P. varia*, showing terminal glandular cells; Fig. 18. T.s. of a portion of rhizome of *P. fissa* showing attachment of paleae. Fig. 19. Vascular structure of a

portion of the rhizome of *P. lanceolata*. Fig. 20. Same, of *P. flocculosa*. Fig. 21. Same, of *P. fissa*. Fig. 22. T.s. of a portion of the cortex of the rhizome of *P. heteractis*. Fig. 23. T.s. of a portion of the root of *P. fissa*. (*b*, branch trace; *c*, outer cortex; *ci*, inner cortex; *e*, epidermis; *en*, endodermis; *l*, leaf trace; *p*, attachment of the palea; *r*, root trace; *rh*, rhizoid; *s*, stalk; *sc*, sclerenchyma sheath).

and the one next to it supply the leaves on one side while the median bundle and one next to it on the opposite side, supply the leaves on the other side, the leaves in the two rows being alternate. Vascular connections to the leaves exhibit varying degrees of complexity in the different species. In the simplest cases like *P. lanceolata* (Text-Fig. 19) the median vascular strand of the rhizome gives off a branch towards the cortex, closely followed by a similar branch from one of the adjacent strands. These branches (leaf traces) curve outwards, pass obliquely through the cortex and enter the leaf base. On passing through the cortex one of the traces gives off a branch on the side away from the rhizome apex. This branch runs parallel to the main traces and becomes oriented on the abaxial side of the leaf base. The leaf traces, as they pass through the cortical sclerenchyma, acquire a common sclerenchyma sheath which continues as the cortical sclerenchyma of the phyllopodium. In *P. adnascens* and *P. varia* vascular connection to leaf originates as in *P. lanceolata* but the traces while passing through the cortex branch to form a larger number of bundles entering the leaf base. Irregular vascular commissures between the trace bundles are common. In *P. heteractis* more than two traces originate, from the dorsal- and one of the lateral-vascular bundles of the rhizome, to supply each leaf. Each of the rhizome bundles gives off two to three branches alternately in close succession, the last formed being bigger than the others. All the branches divide in the cortex, may establish irregular commissures, arrange themselves to form a cylinder and enter the leaf base. Vascular connection to the branch of the rhizome is established by one of the vascular bundles of the rhizome becoming tangentially flattened, with the flanks curving inwards, and entering the branch by passing obliquely through the cortex. The branch trace becomes gutter-shaped in the cortex, twisting slightly so that the concavity faces upwards. On entering the branch it disintegrates into different strands forming a cylinder as in the main rhizome.

In species with short fleshy rhizomes, like *P. beddomeana*, *P. flocculosa* and *P. fissa*, vascular connection to the leaf originates as in *P. heteractis* but is more complex because of the association of the branch trace with it. In *P. beddomeana* and *P. flocculosa* (Text-Fig. 20) the trace formed last from the lateral bundle of the rhizome (trace shown extreme right in Text-Fig. 20) gives off a branch on the adaxial side soon after its origin. This branch (Text-Fig. 20 *b*) curves more sharply than the leaf trace and becomes lateral to it towards the abaxial side on reaching the outer cortex. This is the vascular connection to the branch of the rhizome. In *P. fissa* (Text-Fig. 21) the leaf traces originate as in *P. flocculosa* but the lateral vascular strand of the rhizome immediately after giving rise to the leaf trace becomes flattened with the flanks curving inwards and passes obliquely outwards (Text-Fig. 21 *b*), establishing vascular connection with the rhizome branch. Though formed

axillary to the leaf trace, the sharper curve taken by the branch trace in the cortex of the rhizome makes it abaxially lateral to the leaf trace as in *P. flocculosa*. In some cases the leaf traces may be supplemented by a branch from the rhizome bundle next to the branch trace (Text-Fig. 21).

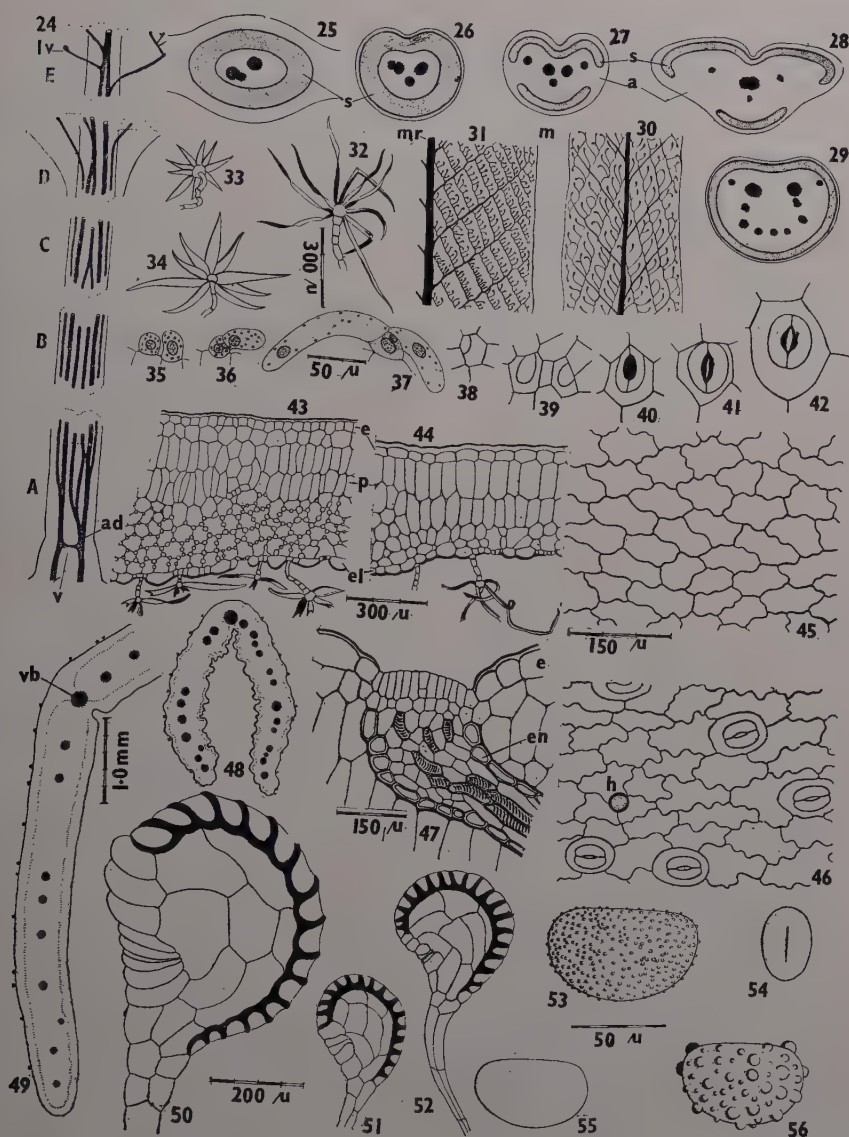
Root traces may be formed irregularly from all the vascular strands of the rhizome but mainly from those near the substratum (Text-Figs. 19-21). The root trace originates as a branch on the outer face of the vascular strand and acquires a sclerenchyma sheath of its own on piercing the sclerenchyma layer of the cortex. This sclerenchyma sheath is continuous with the sclerenchymatous inner cortex of the root.

ROOT

Roots are dark, highly branched and with persistent, dark-brown root-hairs which are thin walled, with dilated bases and usually unicellular. Old root hairs may have the basal region cut off by a cross wall. Root hairs with more septae may occur. The vascular bundle of the root is diarch (Text-Fig. 23). The pericycle is one-layered, thin-walled, regular and with dark contents. Endodermal cells are tangentially elongated, in one layer, smaller than cells of the pericycle and thin walled. The cortex has an inner sclerenchymatous and an outer parenchymatous regions, with an increase of the former related to the age and size of the root. All cortical cells are arranged in radiating rows and are deep-brown in colour, some having black contents. The outer cortical cells are thin walled, polygonal, with dark contents and with prominent vacuoles. The cortical cells facing the protoxylem region on either side remain parenchymatous but the innermost cell, which is bigger than nearby sclerenchyma cells, has a highly thickened lamellated inner wall with branched pits and a thin outer wall. Other sclerenchyma cells have much thickened walls and lack pit connections.

LEAF

Leaves in all the species are simple, stipitate, entire and varying much in size and shape in the different species. Instances of dichotomy (usually towards the apex) are met with. The stipe is articulated to a phyllopodium, which is more prominent in species with fleshy rhizomes. The phyllopodium is clothed by paleae while the stipe and leaf lamina bear only stellate hairs. A dense, brownish felt of stellate hairs covers the stipe in *P. heteractis*, *P. beddomeana*, *P. fissa* and *P. flocculosa*. In the other species, hairs usually occur only on young stipes. The ground tissue of the stipe is parenchymatous and separated into an inner- and an outer-region by a cortical sheath of brown sclerenchyma which is discontinuous because of the presence of two lateral longitudinal bands of aerating parenchymatous tissue (Text-Figs. 27, 28 a). The aerating tissue does not extend into the phyllopodium (Text-Figs. 25, 26, 29). The articulation is formed of a pad of five to six layers of small parenchyma cells which separates the sclerenchyma sheath of the stipe from that of the phyllopodium as in *Drymoglossum* (Nayar, 1957).



TEXT-FIGS. 24-56. Morphology of leaf, sporangia and spores. Fig. 24. Vascular architecture of the stipe and midrib of *P. adnascens* (A, B, C, D and E represent portions at successive heights from the leaf base). Fig. 25. T.s. of base of phyllopodium of *P. adnascens*. Fig. 26. T.s. of apex of same. Fig. 27. T.s. of base of stipe of same. Fig. 28. T.s. of apex of stipe of the same. Fig. 29. T.s. of apex of the phyllopodium of *P. flocculosa*. Fig. 30. Venation pattern of *P. varia*. Fig. 31. Same, of *P. heteractis*. Figs. 32-34. Stellate foliar hairs. Figs. 35-37. Stages in the development of a stellate hair. Figs. 38-42. Surface view of epidermal cells showing stages in the development of stomata in *P. beddomeana*. Fig. 43. T.s. leaf of lamina of

P. adnascens. Fig. 44. Same, of *P. fissa*. Fig. 45. Upper foliar epidermis of *P. varia*. Fig. 46. Lower foliar epidermis of the same. Fig. 47. T.s. of portion of leaf lamina of *P. adnascens*, showing structure of a hydathode. Fig. 48. T.s. of leaf lamina of *P. lanceolata*, when wilted. Fig. 49. T.s. of same leaf, when turgid. Fig. 50. Sporangium of *P. flocculosa*. Fig. 51. Sporangium of *P. lanceolata*. Fig. 52. Sporangium of *P. varia*. Fig. 53. Lateral view of the spore of *P. beddomeana*. Fig. 54. Proximal view of the same. Fig. 55. Lateral view of the spore of *P. flocculosa*. Fig. 56. Lateral view of the spore of *P. adnascens*. (a, aerating tissue; ad, adaxial bundle; e, upper epidermis; el, lower epidermis; en, endodermal cells of vein entering the hydathode; h, base of hair; hy, hypodermal layer; lv, lateral vein supplying the lamina; m, margin of lamina; mr, midrib; p, palisade tissue; s, sclerenchyma; v, vascular commissure between leaf trace bundles; vb, vascular bundle.)

The number of vascular bundles in the stipe differs with the species and the size of the leaf. In small-leaved species like *P. lanceolata* there are two main lateral vascular bundles on the adaxial side and a small median one on the abaxial, all being direct continuations of the leaf traces. At the distal region of the stipe each of the main bundles gives rise to a lateral branch which, on reaching the lamina, forms the first pair of lateral veins. Before entering the lamina the two main vascular bundles unite, forming a single adaxial bundle which soon merges with the abaxial bundle, forming the single vascular strand of the midrib. Main lateral veins of the lamina originate alternately as branches on either side of the midrib bundle. In *P. adnascens* (Text-Fig. 24, A-C) the stipe has usually four vascular bundles, two large adaxial ones and two small abaxials. The latter originate as a single branch (which soon forks) from one of the adaxial bundles (Text-Fig. 24, A). The abaxials fuse into one strand on reaching the lamina (Text-Fig. 24, C) and the confluent strand later fuses with the adaxial bundle on the opposite side so that the midrib usually has only two vascular bundles (Text-Fig. 24, D). As in *P. lanceolata* the vascular bundles fuse together towards the apex of the lamina (Text-Fig. 24, E). In the other species the vascular bundles are many and are arranged in the form of a gutter with the concavity facing the adaxial side (Text-Fig. 29). The two bundles occupying the margins (the adaxial bundles) are larger than the rest and give rise to the first pair of lateral veins of the lamina. All the other lateral veins originate from the adaxial strands after they enter the midrib. Vascular commissures between nearby bundles are common (Text-Fig. 24 v) as are also their fusion and branching. Towards the apex of the leaf the abaxial bundles gradually merge with the adaxials, finally resulting in two strands as in the midrib of *P. adnascens* and as in the latter fuse together into a single strand towards the apex of the leaf.

The upper surface of the mature leaf blade is nearly glabrous. Stellate hairs occur on young leaves. Form and distribution of the stellate hairs on the mature leaf in the various species are described in detail by Giesenhagen (1901) and Ching (1935). Each stellate hair (Text-Figs. 32-34) consists of a uniseriate multicellular stalk with a large polyhedral terminal cell bearing laterally a crown of boat-shaped arms. The stalk cells have thin side walls, collapsible on loss of water, and transverse walls thickened in the form of a biconvex lens. On

juvenile leaves, in all species studied, the stellate hairs are short-stalked (stalk sometimes one cell long) and are restricted to the margins (Text-Fig. 140, s). Most species like *P. adnascens*, *P. lanceolata*, etc., have only one type of stellate hair, while others like *P. beddomeana*, *P. heteractis*, *P. fissa*, etc., possess two types (one with short, broad arms as in the former and another with long, narrow, coiled, cottony arms) mingled together. Each stellate hair originates as a papillate protuberance of an epidermal cell. The papilla is cut off later by a basal wall (Text-Fig. 35), elongates considerably and curves towards the tip of the leaf. The basal region is cut off as a stalk cell (Text-Fig. 36), the upper remaining as one of the arms of the stellate head. The lateral wall of the stalk cell bulges out below the upper wall and is cut off as a lens-shaped cell by a wall at an angle with the upper wall. This elongates into the second arm (Text-Fig. 37). Other arms of the stellate hair originate as lateral branches of the stalk cell (Nayar, 1956). The hairs on juvenile leaves usually have only one or two arms while on adult plants the process is repeated to form the many arms. The stalk cell by repeated transverse divisions forms the multicellular stalk of the adult type of hair. The arms of the young hair are cylindrical and thin walled, but soon develop brownish thickening of the wall on the side facing the leaf epidermis. As the hairs mature, the arms lose their contents and the upper walls collapse giving a boat-like form to the arms.

Venation of the lamina (Text-Figs. 30, 31) is strikingly uniform in all the species. The midrib is prominent and gives off lateral veins alternately. The latter run oblique to the midrib and are connected at regular intervals by subopposite, closely placed secondary veins perpendicular to them, forming a row of narrow areoles. Secondary veins give off two to many tertiary veinlets on the side away from the midrib. The tips of these tertiary veinlets are swollen, curved slightly towards the upper epidermis and may end in obconical hydathodes on the upper surface of the lamina. Rarely the tips of nearby tertiaries unite, the frequency of such unions being more in *P. heteractis*, *P. lanceolata* and *P. varia*. In the latter, a few of the tertiary veinlets may merge rarely with the adjacent secondary vein. The tertiary veinlets are usually simple, but sometimes are forked. The first, and sometimes the second, secondary vein on the adaxial side of each primary vein merges with the midrib. The costal areoles are usually devoid of tertiary veinlets.

The lamina is thick and leathery in all species. The epidermal cells (Text-Figs. 45, 46) are thin walled, devoid of chloroplasts and with the walls bulged outwards, giving a rough appearance to the leaf surface under a hand lens. A parenchymatous, chlorophyllous, one-layered hypodermis of polygonal cells is found beneath the upper epidermis (Text-Fig. 43 *hy*). Beneath it is a double layer of palisade parenchyma. The spongy parenchyma next to it, is three to six layers thick depending on the species. *P. fissa* and *P. beddomeana* differ from the others in possessing a thick cuticle, polygonal spongy parenchyma cells with prominent air spaces, and in lacking a special hypodermal layer (Text-Fig. 44). The lower epidermis is irregular, thin walled, chlorophyllous and interrupted by a large number of stomata (Text-Fig. 46). On

leaves of adult plants the stomata are restricted to the lower epidermis. Each stoma is oval and placed centrally in an epidermal cell. During ontogeny the stomatal mother cell cuts off towards its anterior end a lens-shaped (in surface view) cell which enlarges and develops into a stoma attached to the anterior end of the mother cell (Text-Figs. 38-41). Later, as the stoma rounds off, it becomes detached from the wall of the mother cell and during expansion of the mother cell becomes centrally placed (Text-Fig. 42). In species which lack a thick felt of hairs on the under-surface of the leaf (*P. lanceolata*, *P. varia*) stomata are of the sunken type. The hypodermal-, palisade- and mesophyll- parenchyma have collapsible walls which fold inwards during wilting, so that the breadth and thickness of the leaves are greatly reduced on loss of water (Text-Fig. 48). The length of the leaf is not much affected as the foldings occur only in the plane parallel to the long axis of the leaf. Folded cells are capable of imbibing water and regaining normal shape and size very rapidly (compare Text-Figs. 48 and 49).

The vascular bundles supplying lamina have prominent continuous endodermis with highly thickened, hyaline and pitted inner walls. The hydathodes in which the tertiary veinlets end on the upper surface of the leaf, appear on the leaf-surface as small depressions in which the epidermal cells are smaller, with a regular outline (in contrast to the other epidermal cells which have a wavy outline in surface view) and devoid of any cuticle. They are regularly distributed in *P. heteractis*, *P. beddo-meana*, *P. fissa* and *P. flocculosa*. In *P. varia* and *P. adnascens* they are not so frequent, while in *P. lanceolata* they are rare. The hydathodes (Text-Fig. 47) are multicellular, immersed in the palisade parenchyma and roughly funnel-shaped. The epidermal cells covering the hydathode (Text-Fig. 47 e) are vertically elongated, thin walled and with dense granular contents and prominent nuclei. Below this epidermis is a compact tissue of thin walled, polygonal, parenchyma cells mixed with a few slightly elongated cells having annular and spiral thickenings of the wall. Except the latter, all cells possess dense granular protoplasmic contents and prominent nuclei. A layer of thick-walled cells separates the hydathode from the surrounding leaf tissue and is continuous with the endodermal sheath of the tertiary vein supplying the hydathode.

SPORANGIA AND SPORES

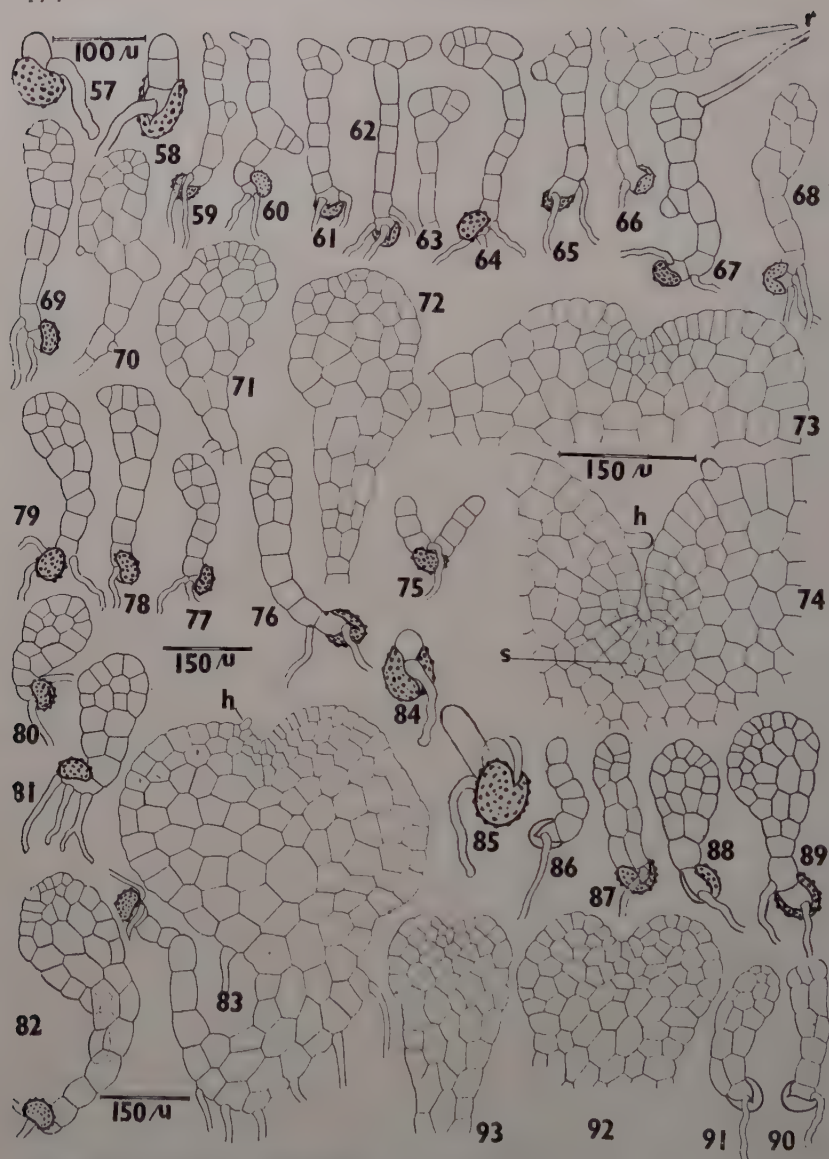
Dimorphism of fertile and sterile leaves manifests itself in varying degrees in the different species (Giesenhagen, 1901; Ching, 1935). Sporangia are aggregated in exindusiate, round sori borne towards the extremities of tertiary veinlets. They occur either all over the under-surface of the leaves or may be restricted to the distal region: the latter condition is the rule in *P. lanceolata* and *P. varia*. Sori occur in depressions on the lower surface of the leaf in *P. adnascens*, *P. lanceolata* and *P. varia*: in the other species hemispherical placenta project out from the general surface of the leaf.

The sori are of the mixed type and have paraphyses resembling the foliar stellate hairs characteristic of the species, but usually with

longer stalks. The stalk of the sporangium is usually four cells long and two cells thick at the base, gradually becoming three cells thick at the top. The annulus abutts on the stalk and consists of 16 to 19 deep-brown cells in *P. lanceolata* and *P. flocculosa* (Text-Figs. 50, 51), 18 to 20 cells in *P. varia* (Text-Fig. 52), 20 to 22 cells in *P. heteractis* and *P. adnascens* and 20 to 24 cells in *P. fissa*. The stomium is of five to ten radially elongated cells with thickening of the radial walls in the lip cells. Spores are bilateral, monolete, concavo-convex in lateral view and with short thin laesurae. The exine is smooth and light-yellow (in untreated, mature spores) in *P. fissa* and *P. flocculosa* (Text-Fig. 55), while in the other species studied, it is bright yellow (in untreated, mature spores) and verrucate, with sparse hemispherical protuberances. In *P. heteractis* and *P. beddomeana* the verrucae are comparatively small (Text-Figs. 53, 54) while in *P. adnascens* (Text-Fig. 56), they are very prominent. On an average the spores are $38 \times 58 \times 40 \mu$ in *P. flocculosa*, $44 \times 69 \times 43 \mu$ in *P. adnascens*, $54 \times 80 \times 53 \mu$ in *P. beddomeana*, $54 \times 86 \times 55 \mu$ in *P. fissa*, $57 \times 74 \times 57 \mu$ in *P. heteractis*, $48 \times 71 \times 46 \mu$ in *P. lanceolata* and $49 \times 67 \times 49 \mu$ in *P. varia* ($P \times E_1 \times E_2$, exclusive of excrescences).

SPORE GERMINATION AND GAMETOPHYTE

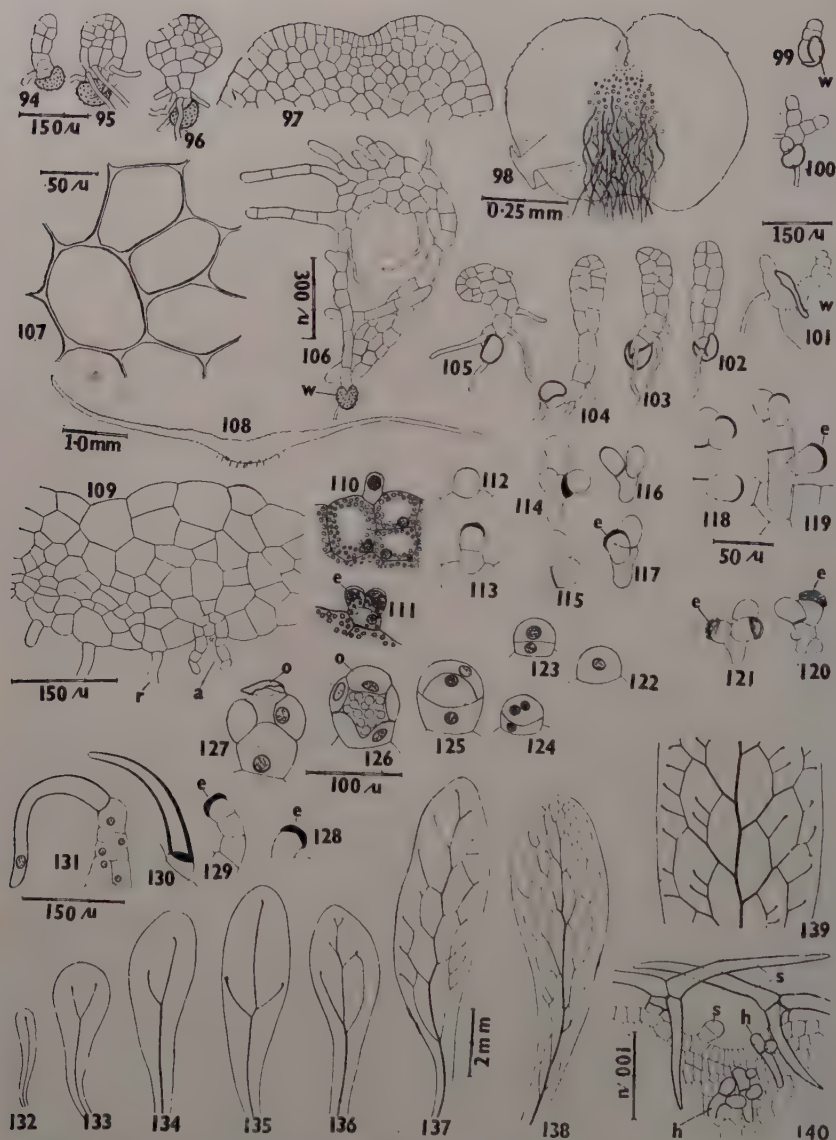
Under laboratory conditions the spores germinate within a fortnight and the first rhizoid protrudes through a longitudinal slit of the exine at the proximal end of the spore. The rhizoid is of a pale brownish-violet colour from the early stages, and is sometimes forked. Chloroplasts are developed in the spores before the formation of the germ filament and a few may be included in the rhizoid. The brownish oil globules within the spores become more prominent during germination. The germ filament originates lateral to the rhizoid, being formed towards one end of the spore, and splits the exine into two halves as it emerges (Text-Figs. 57, 58, 84). Even in rare instances where the germ filament precedes the rhizoid during germination it originates from one end of the spore and not from the middle (Text-Fig. 99). Rarely, two germ filaments originate from a single spore. In such cases they originate from the opposite equatorial ends on the long axis of the spore with the rhizoid in between at the proximal pole (Text-Figs. 75, 101). In *P. varia* more than one germ filament may arise from the same end of the spore (Text-Fig. 85). The germ filament elongates, becomes usually three to six cells long and may branch (Text-Fig. 100), the branching being more frequent under conditions of low illumination and crowding. In *P. adnascens* the cell at the apex of the germ filament may cease to be active, and end in a terminal rhizoid (Text-Fig. 59). In such cases one of the intercalary cells grows out as a branch and continues the growth of the filament (Text-Fig. 60). Under favourable conditions the germ filament is generally 3–4 cells long when longitudinal divisions set in, initiating plate formation. In *P. fissa* and *P. adnascens* (Text-Fig. 61) the germ filament usually becomes four to six cells long before forming the prothallial plate and only the anterior cells take part in it. In *P. adnascens* during the formation of a plate, the cell at the apex may end in a rhizoid (Text-Figs. 66, 67) or may divide longitudinally into two, each of the daughter cells thus produced continuing growth



TEXT-FIGS. 57-93. Morphology of the gametophytes. Figs. 57-58. Spore germination in *P. adnascens*. Figs. 59-72. Stages in the development of the prothallus of *P. adnascens*. Fig. 73. Apex of young prothallus of the same, showing establishment of apical meristem. Fig. 74. Apex of mature prothallus of *P. adnascens*. Fig. 75. Double germ filament of *P. lanceolata*. Figs. 76-83. Stages in the development of prothallus of *P. lanceolata*. Fig. 84. Spore germination in *P. varia*. Fig. 85. Multiple germ filaments of same. Figs. 86-89. Stages in the development of the prothallus of *P. varia*. Figs. 90-92. Stages in the development of the prothallus of *P. fissa*. Fig. 93. Young prothallus of *P. beddomeana*, showing apical meristematic cell. (*h*, marginal hair; *r*, rhizoid; *s*, superficial hair).

(Text-Figs. 61–65). In early stages of development the prothallial plate enlarges by means of diffuse growth (Text-Figs. 69, 70). Later, an apical meristem is established by one or two of the marginal cells at the posterior end of the gametophyte (Text-Figs. 71, 72) and the prothallial plate becomes cordate with the growing meristem at the base of an apical notch (Text-Fig. 73). In healthy gametophytes the meristem consists of two or three actively dividing cells which appear wedge-shaped in surface view with the narrow end facing outwards (Text-Fig. 73). Within three months of growth a midrib is formed by the young cordate prothallus and formation of archegonia is initiated. In *P. varia* and sometimes in *P. lanceolata* during formation of the prothallial plate the cell at the apex of the germ filament itself divides longitudinally, soon after the longitudinal divisions of the intercalary cells (Text-Figs. 76–81, 86–89). One of the daughter cells thus produced may continue growth for some time as a three-sided apical cell or both daughter cells by further divisions may form a marginal meristem which later becomes localized in the characteristic apical notch (Text-Figs. 82, 83). In *P. fissa*, *P. flocculosa* and *P. beddomeana* (Text-Figs. 90–92, 99–105) the development is similar, though occasionally an apical meristematic cell may be established (Text-Fig. 93). Formation of an obconical apical cell by the young gametophytes occurs rarely in *P. adnascens* also (Fig. 68) and this apical cell may persist till the gametophyte develops an apical notch after which it is replaced by an apical meristem. In *P. heteractis* (Text-Figs. 94–97) the germ filament is usually short and soon flattens out as a broad prothallial plate in which growth is diffused in early stages, but becomes later restricted to a group of apical marginal cells (Text-Fig. 97). Spatulate gametophytes kept in darkness revert to the filamentous stage by the cells of the margin growing out as separate filaments (Text-Fig. 106).

The gametophytes in the early stages of development are naked and many of them remain so for a long time during development. Usually as the gametophytes become cordate, marginal hairs are produced by cells close to the meristem (Text-Fig. 83). The hairs (Text-Figs. 110, 112) are small, papillate, thin walled, unicellular, sometimes with a glandular secretion at the tip and generally very sparse. Rarely, two to three celled marginal hairs occur (Text-Figs. 111, 113). After midrib formation club-shaped hairs, which are two to three cells long, curved towards the apical meristem (Text-Fig. 74 s) and with one or two unicellular branches from the upper end of the basal cell, are produced on the under surface of the midrib (Text-Figs. 114–119). The branches have an yellowish, glandular secretion at their tips. The transverse walls of the hair are usually thickened and brownish. All cells of the hair have prominent vacuoles and sparsely distributed chloroplasts. On fully-grown prothalli branched hairs may occur on the upper surface also (Text-Figs. 120, 121). These hairs in some cases are two cells long with three to four branches around the top of the basal cell, appearing star-shaped in surface view. In a few cases, protrusions from the upper surface of the prothalli, bearing a hair with a short, thin walled stalk and a long, curved, thick walled, acicular cell resembling one of the arms of the stellate foliar hair (Text-Figs. 130, 131), are observed. One



TEXT-FIGS. 94-140. Morphology of the gametophytes and young sporophytes. Figs. 94-96. Stages in the development of the prothallus of *P. heteractis*. Fig. 97. Apex of young prothallus of same, showing establishment of apical meristem. Fig. 98. Mature prothallus of *P. fissa*. Figs. 99-105. Stages in the development of the prothallus of *P. flocculosa*. Fig. 106. Abnormal development of young prothallus of *P. adnascens*, induced by intermittent lighting. Fig. 107. Wing cells of mature prothallus of *P. adnascens*. Fig. 108. T.s. of mature prothallus of *P. flocculosa*. Fig. 109. Middle portion of Fig. 108, showing details of structure. Fig. 110. Marginal hair on prothallus of *P. adnascens*. Fig. 111. Abnormal marginal hair

on prothallus of *P. flocculosa*. Figs. 112, 113. Usual forms of marginal hairs of the same. Figs. 114, 115. Superficial hairs of the same. Figs. 116, 117. Superficial hairs on the prothallus of *P. varia*. Figs. 118, 119. Same, of *P. lanceolata*. Figs. 120, 121. Hairs on the upper surface of prothallus of *P. flocculosa*. Figs. 122–127. Stages in the development of the antheridia in *P. adnascens*. Figs. 128, 129. Abnormal superficial hairs on the prothallus of *P. lanceolata*. Fig. 130. Abnormal stellate hair on prothallus of *P. adnascens*. Fig. 131. Abnormal superficial hair in *P. lanceolata*. Figs. 132–139. Juvenile leaves of *P. fissa*, showing progression of the venation pattern. Fig. 140. Apex of the juvenile leaf of *P. flocculosa* (*a*, archegonium; *e*, extracellular cap; *h*, superficial hair; *o*, opercular cell; *r*, rhizoid; *s*, stellate hair; *w*, spore coat).

or more celled uniseriate papillate hairs with apical extracellular caps may occur superficially on some prothalli (Text-Figs. 128, 129).

The mature gametophyte (Text-Fig. 98) is cordate and broader than long (generally 5×7 mm.). The walls of the wing cells are slightly thickened and have a faint violet colour. Prominent collenchymatous thickenings occur at the corners (Text-Fig. 107). The apical meristem consists of a row of wedge-shaped cells, of which the central pair is more prominent (Text-Fig. 74). The midrib is usually five to seven cells thick (Text-Figs. 108, 109). Antheridia are produced, both marginally and superficially by young gametophytes even at the spatulate stage. The mature antheridium is nearly spherical or slightly oblong and has a structure and development which are usual in the higher ferns (Text-Figs. 122–127). The lower wall of the central cell bulges downward and may meet the lower wall of the basal cell or falls short of it. The opercular cell is single and circular in outline. During dehiscence of the antheridium the cap cell is loosened on one side (Text-Fig. 127 *o*) and is gradually pushed off completely. The sperms are pushed out in a mucilaginous mass by the basal wall of the central cell and the inner walls of the peripheral cell bulging inwards towards the centre. Archegonia are of the usual type in advanced leptosporangiates. Both antheridia and archegonia are found on the same gametophyte.

YOUNG SPOROPHYTE

Fertilization occurs profusely in culture. Generally only a single sporophyte is formed per prothallus. The first leaf is linear with a rounded apex. It has a single median vein, ending short of the broad apex of the leaf (Text-Fig. 132). Leaves formed later gradually become oblong (Text-Figs. 133, 134). The median vein is pinnately branched, the branches ending short of the margin (Text-Fig. 135). In succeeding leaves the lower lateral branches fuse towards the margin, forming either a single areole on one side or one areole on each side of the midrib (Text-Fig. 136). When areoles are formed, the extreme tips of the veins remain free, the fusion occurring just behind the tip. Further development leads to the formation of a regular row of areoles on either side of the midrib except towards the tip of the lamina (Text-Fig. 137). Alternating free tips of veins which project beyond the areoles elongate and later form a second row of areoles outside the first, in each case having one free vein included inside (Text-Fig. 138). Included veinlets characteristic of mature plants are formed

generally by the tenth or the eleventh leaf (Text-Fig. 139). The tips of the leaves remain blunt until the eighth leaf which develops an acute tip. The first leaf bears superficial branched hairs (Text-Fig. 140 *h*) curved towards the growing apex when young, and resembling the gametophytic trichomes in structure and ontogeny, but with slender, densely chlorophyllous cells. Stellate hairs with unicellular stalks and one or two arms may occur marginally on the first leaf itself (Text-Fig. 140, *s*). Paleae are produced by the sporophyte when four to five leaves are formed. Early juvenile leaves are non-articulated to rhizome, the articulation appearing only in the fourth to sixth leaf.

DISCUSSION

Pyrrosia, along with *Drymoglossum*, is regarded by some pteridologists (Ching, 1940; Christensen, 1938) as a fern of phymatoid affinity. Ching separates *Pyrrosia* from Pleopeltoid ferns with which Christensen associates it. According to Holttum, (1947, 1949) *Pyrrosia* is evidently related to polypodioid ferns with reticulate veins. He suggests a common origin with *Platynerium*. According to Copeland (1947) *Pyrrosia* is not related to the Phymatoid (Microsoroid) ferns but represents a line of evolution "probably rather nearer to *Pleopeltis*". He includes *Pyrrosia* among his Pleopeltoid ferns and assigns to it a rather advanced position in the group. Holttum suggests an origin along with *Platynerium* from the Dipteroid stock. According to him *Pyrrosia*, *Drymoglossum* and *Platynerium* are evidently specialised genera "not on the main line of evolution of the majority of the Polypodiaceae" (Holttum, 1947, p. 126). *Platynerium* in itself has an ambiguous phylogeny. Ching separates it as a monotypic family—Platyneriaceae—quite distinct from Polypodiaceae "from which it differs in several important characters of primitive type and a very peculiar epiphytic habit" (Ching, 1940, p. 256). Christensen regards it as one of the most primitive elements in his Polypodioideae, while according to Copeland it is an isolated genus with some suggestion of affinity to *Dipteris*, *Cheiropleuria* and *Christiopteris* and resembling *Pyrrosia*. He places it as one of the earliest genera of the Polypodiaceae with the comment that it is not a primitive genus, but one for which a satisfactory place in the classification has not been found.

The present studies tend to support the view that *Pyrrosia* and *Drymoglossum* (Nayar, 1957) are closely related and together have much in common with *Platynerium*, so as to lend support to Holttum's suggestion of a close affinity. The main features of comparison between the three genera are: (a) The rhizome in *Drymoglossum* is thin, long-creeping and sparsely branched as in many species of *Pyrrosia*, like *P. lanceolata* and *P. adnascens*. The different species of *Pyrrosia* exhibit a tendency towards the development of a short, thick rhizome covered by a spongy mass of roots, some species like *P. fissa* and *P. flocculosa* resembling *Platynerium*, in which the rhizome is very short and with spongy masses of roots. (b) The paleae of *Drymoglossum* and *Pyrrosia* are essentially similar in morphology and ontogeny. There is a tendency

towards reduction in size of paleae in the former, some of the paleae resembling the foliar stellate hairs in appearance (but not in ontogeny). The tendency manifest in some species of *Pyrrosia* towards reduction of the terminal glandular cell of the palea is more evident in *Drymoglossum*. The paleae of *Platynerium* are basically similar in ontogeny but in many species the hood does not expand to form a prominent base as in *Pyrrosia* and *Drymoglossum*, so that in the mature paleae the peltate nature is not evident. (c) The structure of the rhizome is nearly identical in the three genera, the ground tissue being entirely parenchymatous, with a distinct cortical sheath of well demarkated sclerenchyma which cuts off the parenchymatous outer cortex from the inner ground tissue. (d) The stelar cylinder of the rhizome is fundamentally similar (Nayar, 1957). The leaf trace in *Drymoglossum* is much reduced compared to *Pyrrosia*, each leaf often receiving only two bundles formed by the division of a solitary leaf trace as in some of the small juvenile leaves of *Pyrrosia*. Occasionally some of the larger leaves of *Drymoglossum* approach the condition in some species of *Pyrrosia*, like *P. lanceolata*, in having two separate traces. In *Platynerium*, possibly due to the increase in thickness of the rhizome the stelar cylinder is much complicated, though of the same basic pattern. *Drymoglossum* exhibits the more primitive condition of the paired nature of the branch traces. Among the different species of *Pyrrosia*, as the thickness of the rhizome increases, the branch trace becomes more and more insignificant, as in *P. fissa* and *P. flocculosa*. (e) The morphology and ontogeny of the stellate foliar appendages and their restricted distribution are, in fact, the closest resemblance between the three genera. As far as is known, such stellate hairs occur only in these three genera in the Polypodiaceae. The stellate hairs, as has already been pointed out, differ so much from the paleae ontogenetically, so as to warrant their consideration as separate entities, evolved independently. The rhizomal and foliar appendages are always distinct and never intermingled. Hairs are absent on the rhizome of *Pyrrosia* and *Drymoglossum*, though in the latter some of the paleae are so much reduced as to appear like the stellate hairs (Nayar, 1957). In some species of *Platynerium*, however, paleae shade off into hairs some of which may be uniseriate. These hairs are unbranched and not of the stellate pattern, though well developed stellate hairs cover the foliar organs densely. In *Drymoglossum*, as in some species of *Pyrrosia* (*P. lanceolata*, *P. adnascens*), there is only one type of stellate hair while in *Platynerium* there are two types of stellate hairs as in species of *Pyrrosia*, like *P. fissa* and *P. flocculosa*. (f) The anatomy and morphology of the stipe are similar the stipe having a distinct sclerenchyma sheath in the cortex as in the rhizome, and possessing prominent aerating tissue. (g) Though the venation pattern of the adult leaves of the three genera are different, the venation pattern of the juvenile leaves is nearly identical, the differentiation occurring only very late in leaf progression (Nayar, 1957). (h) The epidermis, with stomata included within the mother cell, is unique to *Pyrrosia* and *Drymoglossum*, in the Polypodiaceae. (i) The position of the sorus in *Platynerium* and *Drymoglossum* is difficult to be compared with that of *Pyrrosia* due to the acrostichoid spreading of sori. But in *Platynerium*, in which fertile

area is comparatively large, the sporangia in very young fertile leaves are observed to be forming at tips of free ending veinlets and later spreading gradually over the veins, thus indicating a basic pattern as in *Pyrrosia*. (j) The paraphyses in the three genera are nearly identical to the stellate foliar hairs. (k) In *Pyrrosia* the spores of many species, especially of the more primitive ones, have very prominent hemispherical protuberances of the exine, while in *Drymoglossum* some of these protuberances grow out as thick, blunt spines. Many species of *Pyrrosia*, however, have smooth walled spores as in *Platynerium*. (l) The ontogeny and morphology of the gametophytes in the three genera are very closely comparable. The gametophytes are naked in the early stages, developing sparse mammillose marginal hairs and branched superficial hairs towards maturity. Collenchymatous thickening of the corners of wing cells of the prothallus is also a common character. In *Pyrrosia*, as in *Platynerium* (Stokey and Atkinson, 1954) and *Drymoglossum* (Nayar, 1957), an apical meristematic cell is sometimes established rather late in development and is replaced by a meristem. A peculiar feature is the similarity between *Platynerium* and some species of *Pyrrosia* (*P. adnascens*) in the germ filaments terminating in rhizoids. Another interesting feature of comparison is the peculiar colouration of the rhizoids in *Pyrrosia*. As far as is known, this character is shared only by *Platynerium* and *Drymoglossum* among all the ferns. In conjunction with the strong similarities of the sporophyte and gametophyte of the three genera these features may be regarded as indicating a close affinity.

Pyrrosia and *Drymoglossum* exhibit little in common with the Microsorioid (Phymatoid) ferns as to warrant the suggestion of, a close affinity. The main morphological differences which appear to be significant in assessing relationships are:—

(a) Paleae cover the rhizome densely in *Pyrrosia*, while in the Microsorioids the general tendency is to have sparsely distributed paleae. The paleae in *Pyrrosia* bear a glandular terminal cell in some species while in others the terminal cell is only slightly differentiated. Marginal glands are entirely absent contrary to the condition in the Microsorioid ferns. Also, the paleae are nonclathrate in contrast to the clathrate nature in Microsorioids. (b) The characteristic sclerenchyma strands scattered in the ground tissue of the Microsorioid ferns are absent in *Pyrrosia*. Instead, there is a distinct sclerenchyma sheath separating the parenchymatous outer cortex from the inner tissues. In Microsorioids sclerenchyma tissues (other than the slender strands occurring all over) are absent, and as a consequence the rhizome is soft and brittle. (c) The branch trace in *Pyrrosia* is different from that in the Microsorioid ferns, in being a single strand formed usually by one of the main vascular strands of the rhizome curving off to enter the branch. In some species of *Pyrrosia*, in which the branch is associated with the leaf, the branch trace is morphologically still more insignificant, being formed as a minor part of a departing leaf trace. On the contrary the Microsorioid ferns have complicated branch traces having an altogether different origin. (d) The leaves of *Pyrrosia* are distinctly articulated to phyllopodia, the abscission pad being saucer-shaped and formed

of two or three well demarkated layers of narrow parenchyma cells elongated radially. The Microsorioids, however, possess no well differentiated abscission pads: though the leaves are functionally articulated, the abscission tissue is little differentiated from the surrounding tissues. (e) The stipe and phyllopodium of *Pyrrosia* possess prominent sclerenchyma sheaths separating the outer parenchymatous cortex from the inner tissues as in the rhizome. In the Microsorioids on the contrary a well differentiated sclerenchyma sheath is absent, though the cortical cells towards the periphery of the stipe are often thick walled the thickening increasing towards the peripheral layers. An intracortical sheath as found in *Pyrrosia* does not, however, occur in any of the Microsorioids. (f) *Pyrrosia* possesses well differentiated, prominent, lateral aerating bands in the stipe contrary to the condition in the Microsorioids. (g) The foliar appendages of *Pyrrosia* are characteristic and not similar to the club-shaped foliar hairs of the Microsorioids. The stellate hairs of *Pyrrosia*, as has already been pointed out, are morphologically distinct entities. (h) The venation pattern of *Pyrrosia* is characteristic of the genus and is not comparable to the complicated venation patterns of the Pleopeltoids or Microsorioids. In the latter the complicated irregular network is formed mainly by highly branched tertiary veins forming secondary areoles within the primary ones. The tertiaries, at least in the juvenile leaves where they are easily traceable due to less complicated venation patterns, originate mostly from the secondaries on the side facing the midrib and run towards the midrib. In *Pyrrosia* secondary areoles are not formed and the tertiaries are formed on the opposite side of secondaries, running away from the midrib. Usually the tertiaries are unbranched and in most cases a large number of them originate regularly from the secondary veins on the side away from the midrib resulting in the characteristic venation pattern. In *Drymoglossum*, due to the extreme reduction of the lamina, this difference is not much noticeable, while in *Platyserium* the adult leaf offers no scope of comparison. However, the juvenile leaves in these genera resemble those of *Pyrrosia*. In the Microsorioid ferns the juvenile leaves after forming a row of areoles on either side of midrib, form branched or unbranched free ending veinlets running towards the midrib, even before the primary veins begin branching at the tip (in later formed leaves) preparatory to formation of other rows of areoles outside the first row. In *Pyrrosia*, *Platyserium* and *Drymoglossum*, such veinlets, however, are never formed in the juvenile leaves. Many rows of areoles may be formed on either side with no free included veinlets in any of them (i.e., the venation pattern is closed in the juvenile leaves of *Pyrrosia* while in the Microsorioids it is open). Free-ending tertiary branches originate later, but on the opposite side of the secondaries compared to Pleopeltoids, Microsorioids, Drynarioids, etc. (i) Epidermal hydathodes as occurring in *Pyrrosia* are widely distributed among polypodiaceous ferns. In the Microsorioid ferns hydathodes occur terminating the veins in all juvenile leaves, the apex of the median vein of the first juvenile leaf itself often ending in a hydathode. In *Pyrrosia* on the contrary the juvenile leaves do not bear any hydathodes, the hydathodes developing

only late in development, usually after the formation of tertiary veins. The main vascular strand of the lamina (midrib) of the juvenile leaves of Pleopeltoids and Microsorioids terminate in a superficial hydathode which, as the midrib elongates in later formed leaves, becomes apical on the margin (not on the upper surface). In *Pyrrosia* such a condition is not observed. Formation of hydathodes appears to be a secondary feature in the genus, acquired independently. It is interesting to note that hydathodes are almost absent in some species of *Pyrrosia* and are lacking in *Drymoglossum*. (j) A well differentiated palisade tissue occurs in the leaves of *Pyrrosia* in contrast to the undifferentiated mesophyll tissue in the leaves of the Microsorioid ferns. (k) The foliar epidermis of Pyrrosioid ferns with the stomata placed towards the centre of the mother cells, is uncomparable to the foliar epidermis of the Microsorioids. (l) Sporangia occur superficially over veins especially over the vein plexuses in Microsorioids and most other groups of net-veined Polypodiaceae. *Pyrrosia* is much different in this respect, with the sporangia restricted to tips of free ending veinlets. (m) The spores of Microsorioid ferns, as in the majority of Polypodiaceae, are smooth walled and hyaline. Spores with narrow spines are found in some of the Microsorioid derivatives like *Colysis*. But in *Pyrrosia* many species, especially the more primitive ones, have prominent hemispherical protuberances on the exine, though a tendency to form smooth-walled spores is evident among the different species. In *Drymoglossum* some of the protuberances elongate as massive spines. (n) The mature gametophyte of Pyrrosioids is thin and cordate with characteristic superficial hairs and small, naked, mammillose marginal hairs. In *Phymatodes* (*sensu stricto*), with which relationship is often suggested, though the mature prothallus is thin and cordate, it is profusely hairy with prominent, papillate, capped hairs all over the margin and the under surface (unpublished data). The gametophytes of *Phymatodes* (*sensu stricto*) have a Pleopeltoid type of development in which a successive series of apical cells, each ending in a hair and being succeeded by a secondary apical cell formed laterally, are formed. The apical meristem, when established, is lateral. In *Pyrrosia* the type of development of prothallus is entirely different. Also, the gametophytes of *Pyrrosia* remain naked till quite late in development contrary to the profusely hairy young gametophytes of *Pymatodes*. As regards the other Microsorioids the gametophyte is of the ribbon-like type in the *Microsorium pteropus*-group of species as well as in the related genera like *Colysis* (unpublished data). In the *Microsorium punctatum* group of species also the prothallus is different from that of *Pyrrosia*, even though of the cordate type. The collenchymatous thickening of the wing cells of the *Pyrrosia* gametophytes as well as the characteristic colouration of their rhizoids are absent among the Microsorioid ferns. (o) The basic chromosome number in *Pyrrosia* is $n = 37$ (Manton, 1954) while in all the Microsorioids and their near relatives the chromosome number as far as is known (Manton, 1950, 1953, 1954; Nayar, 1958) is characteristically $n = 36$.

As regards the Pleopeltoid ferns *Pyrrosia* differs in many significant morphological characters which tend to question the validity of the hypothesis of a close relationship between them;—

(a) The paleae in the Pleopeltoids bear profuse marginal glandular hairs, while in *Pyrrosia* they are absent. (b) Paleae spread over the foliar organs in Pleopeltoids (though the foliar paleae are slightly different in shape) while in *Pyrrosia* the paleae extend only up to the phyllopodium, ending abruptly at the articulation. As has been shown, the ontogeny of the stellate foliar hairs of *Pyrrosia* is different from that of the paleae so as to suggest that the two are altogether different entities. Also, the stellate hairs are strictly foliar. Thus the stellate foliar hairs of *Pyrrosia* and *Drymoglossum*, do not appear to be the forerunners of the peltate paleae of the rhizome. The hairs seem to have evolved on an entirely separate line, probably from simple epidermal hairs of ancient predecessors. The evolution of the stellate hairs in *Pyrrosia* does not appear to be in the direction of condensation of the arms of the hair or towards their lateral fusion so as to derive hypothetically the peltate paraphyses and other foliar appendages as in the Pleopeltoids. On the contrary there is a progressive evolution within the genus towards development of narrow, much elongated, curled, cottony arms which apparently are more effective as a protective device than the short-armed hairs. Many species of *Pyrrosia* have both types mingled together, while quite a few species, which exhibit other primitive morphological features, have only the short-armed type of hair as in *Drymoglossum*. Also, only the latter type of hairs occur on the early juvenile leaves, the long-armed types being formed late in development. (c) The venation pattern of *Pyrrosia* is vastly different from the Pleopeltoid venation. (d) Among the Pleopeltoid ferns the sori occur characteristically over complex vein plexuses, while in *Pyrrosia* the sori occur towards tips of free ending veinlets. (e) Peltate, shield-like paraphyses with the ontogeny similar to that of the paleae and bearing terminal and marginal glandular hairs are characteristic of the Pleopeltoids. The paraphyses of *Pyrrosia* are stellate hairs like the foliar trichomes, with the ontogeny different from that of the paleae and devoid of glandular hairs. (f) The spores of Pleopeltoid ferns differ from those of *Pyrrosia* as the Microsorioid spores do. (g) The prothalli of Pleopeltoids are generally profusely hairy from very young stages contrary to the condition in *Pyrrosia*. An apical meristematic cell is established in them, early in development. The apical cell soon ends in a hair and is succeeded by another formed lateral to it. The process may be repeated and when a multicellular meristem is established it is formed lateral to the last formed apical cell. The type of development in *Pyrrosia* is different. (h) The juvenile leaves of *Pyrrosia* bear branched hairs, resembling the superficial gametophytic hairs, mixed with simple stellate hairs, contrary to the simple papillate hairs in the Pleopeltoids. The progression of the venation pattern in Pleopeltoids is more or less resembling the condition in the Microsorioid ferns and thus different from that of *Pyrrosia*.

The above comparisons seem to point to the conclusion that *Pyrrosia*, possibly, is distinct from most other Polypodiaceae in its phyletic history. The affinities of *Pyrrosia* are to *Platyserium* on the one hand and to *Drymoglossum* on the other. Pleopeltoids and Microsorioids with which affinities have been suggested in the past appear to belong to independent

lines of descent quite distinct from *Pyrrosia* and allies. Within the genus the primitive element appears to be represented by species with the least structural adaptations of the rhizome. In these the rhizome is thin and long creeping, with the branches unassociated with leaves, the branch trace being formed by one of the main vascular strands of the rhizome curving out through the cortex as in *P. varia*. The leaf lamina shows a tendency to fork, especially towards the apex. Fertile and sterile leaves are alike and sori occur all over the leaf. The foliar stellate hairs are uniform and of the short-armed type. Hydathodes are very few and may be absent in some. The spores are with very prominent excrescences of the exine and thick walled. The germ filament broadens by division of all cells including the basal one and is generally short. From this stock might have evolved species like *P. adnascens* exhibiting varying degrees of dimorphism of the frond. Another line of advancement is in the condensation of the rhizome from a long, thin one to short, stout, and usually fleshy as in *P. fissa*, *P. flocculosa*, etc. The branches become associated with leaves, the branch traces originating as parts or the vascular strands constituting the leaf trace. The spores tend to become smooth walled and during development of the gametophyte, the germ filament is longer with only the anterior cells taking part in broadening. Associated with increase in thickness of the rhizome are structural changes in the leaf lamina. The lamina becomes thinner and may lose the specialised hypodermal layer. The leaves lose the capacity to roll up during wilting. The incidence of hydathodes increases on the upper epidermis. The leaf lamina in some cases exhibit a tendency to develop a pinnately lobed margin as in *P. fissa*.

SUMMARY

Detailed morphology of the sporophytes and gametophytes of seven Indian species of *Pyrrosia* is studied. The rhizome in the genus is either thin and long creeping or thick and short, depending on the species. Paleae are peltate, capable of absorbing water and restricted to the rhizome and phyllopodia. Vascular cylinder is a "false dictyostele" and leaf traces originate as branches from the main bundles of the rhizome, increasing in complexity with the increase in the size of the leaves depending on the species. Branch traces are formed by one of the main vascular strands of the rhizome slanting off obliquely towards the branch base and are not associated with leaf traces in species with long, thin rhizomes. In species with short rhizomes, each leaf has a branch associated with it, the branch traces originating laterally from the adaxial side of the leaf traces. Foliar trichomes are stellate hairs which are ontogenetically distinct from the paleae. The venation is characteristic and the free ending tips of the veinlets usually terminate in superficial hydathodes on the upper surface of the leaf. The frequency of the hydathodes varies with the species. Stomata are situated towards the middle of the mother cell and are not attached to the side walls. Various degrees of dimorphism of leaves are met with in the different species. Sori are round and situated superficially on free ending veinlets towards their apices. Paraphyses resemble foliar hairs. Sporangial

stalks are three cells thick at the top. The spores are bilateral with the exine either smooth or variously verrucate depending on the species. Spore germination results in a germ filament which is three to six cells long and forms a cordate prothallus by an apical multicellular meristem generally without the formation of an apical meristematic cell. Terminal cell of the germ filament may end in a rhizoid in *P. adnascens*. Mature gametophytes are cordate and thin possessing unicellular, club-shaped, sparse, marginal hairs and characteristic branched, multicellular superficial hairs. Early juvenile leaves are simple, each with a single median vein and bearing hairs similar to superficial prothallial hairs. It is concluded that *Pyrrosia* is quite distinct from the Pleopeltoid and Phymatoid ferns, but is closely related to *Platyserium* on the one hand and *Drymoglossum* on the other.

ACKNOWLEDGEMENTS

Thanks are due to Prof. K. N. Kaul, Director, National Botanic Gardens, Lucknow, for the keen interest he has evinced in this work. A part of this work was done in the Botany Laboratory of the Gauhati University, Assam, and I am thankful to Professor H. K. Baruah of the University for the kind help he has rendered. I am grateful to Prof. R. E. Holttum for kindly going through and criticising the manuscript.

REFERENCES

- CHING, R. C. 1935. On the genus *Pyrrosia* Mirbel from the main land of Asia including Japan and Formosa. *Bull. Chin. bot. Soc.* 1: 36-72.
- . 1940. On natural classification of the family Polypodiaceae. *Sunyatsenia* 5: 201-68.
- CHRISTENSEN, C. 1938. Filicineae. Verdoorn's *Manual of Pteridology*, The Hague.
- COPELAND, E. B. 1947. *Genera Filicum*. Waltham, Mass., U.S.A.
- ERDTMAN, G. 1952. *Pollen Morphology and Plant Taxonomy*. Stockholm.
- GIESENHAGEN, K. 1901. *Die farn gattung Niphobolus, Ein monographie*. Jena.
- HOLTUM, R. E. 1947. A revised classification of leptosporangiate ferns. *J. Linn. Soc. (Bot.)* 53: 123-58.
- . 1949. The classification of ferns. *Biol. Rev.* 24: 267-96.
- MANTON, I. 1950. *Problems of Cytology and Evolution in the Pteridophyta*. Camb. Univ. Press.
- . 1953. The cytological evolution of the fern flora of Ceylon. *Symp Soc. Exptl. Biol.* 7, *Evolution*: 174-85.
- . 1954. Appendix to R. E. Holttum's *Flora of Malaya*. 2: *Ferns*. Singapore.
- NAYAR, B. K. 1954. Studies in Polypodiaceae—II. Contributions to the morphology of *Pseudodrynaria coronans* (Wall.) C.Chr. *Phytomorphology* 4: 379-90.
- . 1955. Studies in Polypodiaceae—III. *Loxogramme* (Bl.) Presl. *J. Indian bot. Soc.* 34: 395-407.

- NAYAR, B. K. 1956. Correlation between gametophytic and sporophytic trichomes in ferns. *Sci. and Cult.* **21**: 455-57.
- . 1957. Studies in Polypodiaceae—IV. *Drymoglossum* Presl. *J. Indian bot. Soc.* **36**: 169-79.
- . 1958. Studies in Polypodiaceae—V. Cytology of *Celysis pedunculata* (Hk. et Grev.) Ching. *Sci. and Cult.* **24**: 181-82.
- . 1960. Morphology of two Indian species of *Bolbitis*. *J. Indian bot. Soc.* **39**: 259-77.
- AND P. KACHROO. 1953. Studies in Polypodiaceae—I. Contributions to the morphology of *Drynaria* Boey: *D. quercifolia* (L.) J. Sm. and *D. propinqua* (Wall.) J. Sm. *Phytomorphology* **3**: 411-23.
- PANDÉ, S. K. 1935. Notes on the anatomy of a xerophytic fern *Niphobolus adnascens* from Malay Peninsula. *Proc. Indian Acad. Sci.* **18**: 556-64.
- STOKEY, A. G. 1951. The contribution by the gametophyte to the classification of the homosporous ferns. *Phytomorphology* **1**: 39-58.
- AND ATKINSON, L. R. 1954. The gametophyte of five species of *Platycerium*. *Ibid.* **4**: 169-72.

THE FORESTS OF NORTH KANARA DISTRICT

I. Scrubs

BY R. K. ARORA*

Botanical Survey of India, Poona

(Received for publication on November 10, 1959)

THE district of North Kanara, between Lat. $13^{\circ} 55' N.$ and $15^{\circ} 31' N.$ and Long. $74^{\circ} 9' E.$ and $75^{\circ} 4' E.$ along the Western Ghats, assumes a significant importance due to its richness in vegetation and the bewildering variety of flora it contains. The forests of this region, which cover nearly four-fifth of the area, about 3,910 sq. miles, are situated on the south-east edge of the Deccan plateau abutting the sea on the west, North Malabar on the south and Belgaum district on the north (Text-Fig. 1).

Geologically, North Kanara is formed of unclassified rocks, mainly granite, gneiss or laterite. The underlying rock at places may also be metamorphic (quartzites, slate, shale, etc.) especially in the north-eastern regions. The hill-tops are generally covered with laterite, with rock outcrops on the surface. Alluvial deposits also occur and alluvial soils bear good teak/bamboo type forests.

The climate of the area is typically monsoonic. Rainfall varies from about 100 to 125 cm. in the north-eastern sides to over 500 cm. in the central, southern and coastal areas. Rainfall patterns of the main towns are shown in Text-Fig. 2. Temperature remains moderate, showing more extremes in the northern side ($50-95^{\circ} F.$) than in the coastal and central areas ($75-90^{\circ} F.$).

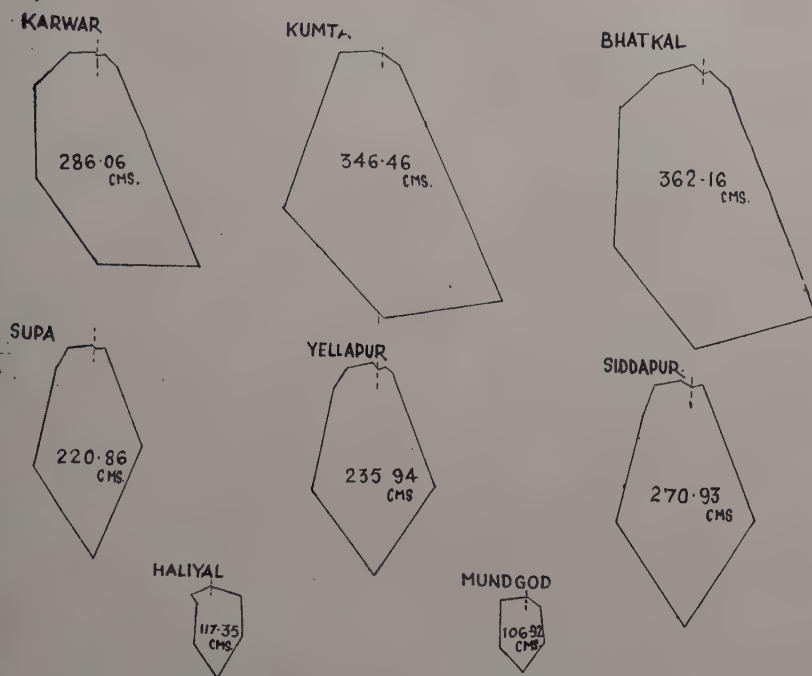
The forests of North Kanara district have little been explored. A good deal of information on these is available from the forest working plans (Davis, 1927; Kesarcodi, 1932; Kaikani, 1945; Mavin Karve, 1955; Coelho, 1956) which contain a good account of the vegetation though mainly dealing with the economic aspects of the forest management and utilization. A popular account of these forests is also given by Mirchandani (1941) but to no details. Much of the work, however, seems to be done on the problems relating to the regeneration and better growth of economic species or of forest lands in general (Dhaneshwar, 1939, 1941).

Recently a small note by Santapau (1955) has appeared in which he records his diary of visit in some forests of N. Kanara giving the botanical composition of a few forests visited by him near Dandeli, Sirsi and Jog.

* Present address: Asst. Ecologist, Botanical Survey of India, Calcutta.



TEXT-FIG. 1.



TEXT-FIG. 2. Rainfall Patterns.

Three different types of forests are met with in N. Kanara.

- (a) Evergreen
- (b) Deciduous
- (c) Scrub

There is not very definite and clear demarcation in these types from one another, and so intermediate types are often to be seen. Thus adjoining a scrub may be a deciduous forest; and in an area with a deciduous vegetation (Teak forest), bamboo types or often a semi-evergreen forest with species like *Tabernaemontana heyneana*, *Callicarpa tomentosa*, *Xylia xylocarpa* and others may be seen. But, in general, the distribution of these types seems to be governed by the factors of the locality, the amount of rainfall and soil.

Studies on the floristics of this area are being made since 1957. The composition of the principal vegetation types has been studied. In the present paper only the scrub forests have been dealt with and in the next of this series, deciduous and evergreen types will be described. Successional trends of the different communities studied under different forest types will also be discussed.

The scrub forests of N. Kanara which are mainly biotic/bioedaphic types are distributed in the north-north-east of the district, along the coast (Western limits) and in the plateau between Sirsi-Siddapur. The floristic composition, nature of soil, rainfall and temperature, etc., differ in the different areas, bearing scrub forests. Three subtypes may be described as follows:—

North-eastern scrub .. Deciduous type	
Plateau scrub }	.. Evergreen type
Coastal scrub }	

NORTH-EASTERN SCRUB

This scrub is developed on black coarse soil. Rainfall varies from 80–125 cm. in these areas and temperature attains a maximum of 100° F. Following communities have been studied:

Ixora-Gymnosporia type (a) .. Table I.

Ixora-Gymnosporia type (b) .. Table II.

Butea type .. Table IV.

Ixora-Gymnosporia type (a) has been studied along the north-eastern limits of the district adjoining Dharwar. The vegetation exists in thickets, and the adjoining forests have an open canopy. The soil is brownish-black, hard, rocky and shallow at places. The chief components of the scrub are *Ixora parviflora* and *Gymnosporia montana*. Thorny species of *Randia*, *Zizyphus* and *Flacourtia* are generally observed. The undergrowth consists of annuals, chiefly of few grasses and herbs. *Curculigo orchoides*, *Elephantopus scaber*, *Rungia*, *Oxalis*, *Stachytarpheta indica*, *Clerodendron serratum* and grasses like *Oplismenus*, *Setaria glauca* are commonly noted.

Climbers are few and are occasionally noted in the thickets. Generally, *Acacia concinna*, *Celastrus paniculata*, *Jasminum malabaricum* and *Asparagus racemosus* are present.

This type develops into a forest which has more of stunted scrubby tree species, i.e., *Ixora-Gymnosporia* type (b) which has been studied near Mandihal and is developed on a hard stratum on black soil.

The forest is composed of few scattered scrubby trees of *Tectona grandis*, *Terminalia tomentosa*, *Lagerstroemia lanceolata* and others. The vegetation is not found in thickets but is more or less uniformly spread, forming rather a denser canopy than that noted under the first type.

Shrubby growth is chiefly of *Carissa congesta*, *Flacourtia indica*, *Securinega virosa*, *Ixora parviflora*, *Gymnosporia montana*, *Randia brandisii*, *Bridelia stipularis* and others.

TABLE I

Ixora-Gymnosporia Type (a)

Date	18-9-1958
Locality	Dharwar-Haliyal Road (2nd mile stone)
Aspect	Undulating land
Geology	With quartzite at places
Soil	Coarse, hard, blackish soil
No. of quadrats studied	10

Name of the plant	% Occurrence *
Trees:	
<i>Anogeissus latifolia</i>	10
<i>Terminalia tomentosa</i>	10
Shrubs and climbers:	
<i>Acacia concinna</i>	10
<i>Argyrea cuneata</i>	50
<i>Asparagus racemosus</i>	20
<i>Carissa congesta</i>	40
<i>Flacourtia indica</i>	20
<i>Gymnosporia montana</i>	80
<i>Ixora arborea</i>	100
<i>Lantana camara</i>	100
<i>Randia</i> sp.	30
<i>Zizyphus oenoplia</i>	40
Ground flora:	
<i>Clerodendron serratum</i>	20
<i>Curculigo orchoides</i>	30
<i>Elephantopus scaber</i>	30
<i>Eragrostis amabilis</i>	40
<i>Oplismenus</i> sp.	+
<i>Oxalis corniculata</i>	+
<i>Rungia parviflora</i>	+
<i>Setaria glauca</i>	+
<i>Stachytarpheta indica</i>	+

* Calculated on the basis of the total number of quadrats studied, i.e., *Anogeissus latifolia* 10% means that out of 10 quadrats laid, *Anogeissus* has been recorded only in one.

TABLE II
Ixora-Gymnosporia Type (b)

Date	2-6-1958
Locality	Mandihal-Haliyal road
Aspect	Undulating land
Geology	Quartzite at places
Soil	Hard, rocky, coarse soil grayish black
No. of quadrats studied ..	10

Name of the plant	% Occurrence
Trees:	
<i>Gmelina arborea</i>	20
<i>Holarrhena antidysenterica</i>	10
<i>Lagerstroemia lanceolata</i>	10
<i>Lannea coromandelica</i>	10
<i>Tectona grandis</i>	30
<i>Terminalia tomentosa</i>	20
Shrubs and climbers:	
<i>Abrus precatorius</i>	20
<i>Acacia concinna</i>	60
<i>Asparagus racemosus</i>	60
<i>Aspidopterys cordata</i>	10
<i>Bridelia stipularis</i>	40
<i>Carissa congesta</i>	80
<i>Celastrus paniculata</i>	40
<i>Clematis triloba</i>	30
<i>Cylista scariosa</i>	30
<i>Diploclisia glaucescens</i>	10
<i>Dioscorea pentaphylla</i>	20
<i>Flacourtia indica</i>	50
<i>Gymnosporia montana</i>	50
<i>Hemidesmus indicus</i>	30
<i>Ipomea</i> sp.	30
<i>Ixora parviflora</i>	50
<i>Jasminum malabaricum</i>	40
<i>Lantana camara</i>	80
<i>Randia brandisii</i>	30
<i>Securinega virosa</i>	40
<i>Zizyphus oenoplia</i>	60
<i>Zizyphus rugosa</i>	20

TABLE II (Contd.)

Name of the plant	% Occurrence
Ground flora (herbs and tree seedlings):	
<i>Albizzia</i> sp.	30
<i>Bauhinia racemosa</i>	10
<i>Cassia fistula</i>	40
<i>Curculigo orchioides</i>	80
<i>Cyperus</i> sp.	+
<i>Elephantopus scaber</i>	+
<i>Fimbristylis</i> sp.	+
<i>Grewia tiliaefolia</i>	10
<i>Mallotus philippensis</i>	40
<i>Oplismenus burmannii</i>	+
<i>Oxalis corniculata</i>	+
<i>Phoenix</i> sp.	+
<i>Polygonum</i> sp.	+
<i>Santalum album</i>	10
<i>Tectona grandis</i>	10
<i>Terminalia tomentosa</i>	10

The chief climbers are: *Acacia concinna* and *Asparagus racemosus* with others like *Dioscorea*, *Cylista*, *Celastrus*, *Clematis*, *Jasminum malabaricum*.

Zizyphus rugosa and *Zizyphus oenoplia* are the common aggressive liana-type shrubs.

The ground flora species are: *Elephantopus scaber*, *Oxalis*, *Fimbristylis*, *Curculigo* and few grasses like *Oplismenus*. Tree seedlings of deciduous species are quite common, i.e., seedlings of *Cassia fistula*, *Mallotus philippensis* with saplings of *Santalum album*, *Bauhinia* sp., *Albizzia* sp., etc. Teak regeneration and the regeneration of other deciduous species like *Terminalia tomentosa* is poor, perhaps because of shallow soil and hard substratum.

This type develops into a deciduous forest of *Teak-Terminalia* type (Table III) studied near Bhanasgiri on Dharwar-Haliyal road, along the north-east of the district.

This *Teak-Terminalia* type forest is developed on alluvium, where soil is deep blackish-brown and mixed with humus. Forest canopy is denser and not open like other scrubby jungles described above. Trees are coppiced and stunted. The chief components of this forest are *Tectona grandis* and *Terminalia tomentosa* with other species like *Anogeissus latifolia*, *Madhuca indica*, *Diospyros melanoxylon*, *Buchanania lanzan* and *Careya arborea*.

Amongst the shrubs, which are rather scattered and do not occur in thickets, *Gymnosporia montana*, *Ixora parviflora*, *Zizyphus* species

TABLE III
Teak-Terminalia Type

Date	..	19-9-1958	
Locality	..	Bhanasgiri	Dharwar-Haliyal road
Aspect	..	Gentle slope	
Geology	..	Alluvium	
Soil ..	..	Alluvial, blackish grey	
No. of quadrats studied	10		10
Name of the Plant		% Occurrence	% Occurrence
Trees :			
<i>Adina cordifolia</i>		10	..
<i>Anogeissus latifolia</i>		40	20
<i>Buchanania lanzan</i>		20	..
<i>Careya arborea</i>		10	20
<i>Diospyros melanoxylon</i>		10	..
<i>Madhuca indica</i>		30	10
<i>Meyna laxiflora</i>		20	..
<i>Tectona grandis</i>		100	90
<i>Terminalia tomentosa</i>		100	100
<i>Terminalia paniculata</i>		20	..
Shrubs and climbers :			
<i>Argyreia cuneata</i>		10	20
<i>Asparagus racemosus</i>		10	20
<i>Cryptolepis buchanani</i>		..	10
<i>Dioscorea oppositifolia</i>		20	..
<i>Gymnosporia montana</i>		50	20
<i>Holarrhena antidysenterica</i>		..	10
<i>Ixora parviflora</i>		20	..
<i>Lantana camara</i>		40	40
<i>Vitis</i> sp.		10	10
<i>Zizyphus oenoplia</i>		30	10
<i>Zizyphus xylopyra</i>		10	..
Ground flora (herbs and tree seedlings):			
<i>Anogeissus latifolia</i>		40	10
<i>Careya arborea</i>		10	20
<i>Curculigo orchoides</i>		30	30
<i>Elephantopus scaber</i>		100	80
<i>Fimbristylis</i> sp.		30	100
<i>Gymnosporia montana</i>		10	10
<i>Oldenlandia</i> sp.		20	10
<i>Oxalis corniculata</i>		100	100
<i>Tectona grandis</i>		40	30
<i>Terminalia tomentosa</i>		60	30

TABLE IV
Butea Type

Date	22-3-1959
Locality	Mundgod-Hubli Road 6th mile
Aspect	Level area, water-logged
Geology	Rock hidden: soil deep, with reddish grains
Soil	Black, surface cracked
No. of quadrats studied ..	20

Name of the plant	% Occurrence
<i>Argyreia cuneata</i>	5
<i>Bridelia stipularis</i>	70
<i>Butea monosperma</i>	80
<i>Careya arborea</i>	45
<i>Carissa congesta</i>	55
<i>Cassia auriculata</i>	10
<i>Cocculus villosus</i>	5
<i>Flacourtia indica</i>	25
<i>Ixora parviflora</i>	20
<i>Kirjenalia reticulata</i>	40
<i>Jasminum malabaricum</i>	10
<i>Lantana camara</i>	50
<i>Zizyphus oenoplia</i>	5
<i>Zizyphus rugosa</i>	5
<i>Zizyphus xylopyra</i>	10

are frequently noted. *Dioscorea pentaphylla* and *Asparagus racemosus* with other climbers are often seen.

The ground flora consists of few herbs, grasses and tree seedlings. *Curculigo*, *Fimbristylis* and *Oxalis* with tree saplings of *Tectona grandis*, *Anogeissus latifolia*, *Terminalia tomentosa* and *Careya arborea* are present.

Teak-Terminalia type seems to be the stable community and represents a climax type developed from *Ixora-Gymnosporia* type scrub.

BUTEA TYPE

The type has been studied along Mundgod-Hubli road on a level area, which showed signs of water logging. The surface was cracked

and sunken at places. Stunted trees of *Butea monosperma* were common, along with *Careya arborea* which had a percentage occurrence of 45.

The thorny shrubs occur in thickets of few each as in *Ixora-Gymnosporia* type. A composite thicket consisted of species like *Carissa congesta*, *Bridelia stipularis*, *Flacourtia indica*, *Kirjenalia reticulata*, *Zizyphus* sp., *Ixora parviflora*, *Jasminum malabaricum*, *Celastrus paniculata* and others.

The *Butea* type, too, may also develop into a *Teak-Terminalia* forest under better drainage conditions.

In all the communities described above *Lantana camara* is very common. At places it is aggressive, thus hindering in the development of the tree seedlings, though at times it may help to protect them from the harmful effect of animals, or other biotic interferences.

PLATEAU SCRUB

This type includes the scrub forests studied along Sirsi-Siddapur plateau. Rainfall in these areas is about 250 cm. per annum or more. Temperature variation here is less. The rock is hard laterite giving red laterite soil. Along the hillocks, rock outcrops at surface. The soil too is rocky and hard.

Syzygium-Ixora-Glochidion-Gardenia type has been studied near Siddapur in the south-east of the district (Table V).

TABLE V

Syzygium-Ixora-Glochidion-Gardenia Type

Date	..	22-3-1959	
Locality	..	Minor forest, Siddapur	Minor Forest, Hosur
Aspect	..	Hilly area	Hilly area
Geology	..	Laterite	Laterite
Soil ..	..	Red	Red
No. of quadrats studied		20	20
Name of the plant		% Occurrence	% Occurrence
<i>Bridelia stipularis</i>		30	30
<i>Butea monosperma</i>		5	..
<i>Canthium dicoccum</i>		20	10
<i>Careya arborea</i>		15	50
<i>Carissa congesta</i>		60	10
<i>Celastrus paniculata</i>		15	..

TABLE V (Contd.)

Name of the plant	% Occurrence	% Occurrence
<i>Cyclea peltata</i>	..	5
<i>Dalbergia sympathetica</i>	40	5
<i>Flacourtia indica</i>	10	..
<i>Flacourtia montana</i>	10	..
<i>Gardenia gummifera</i>	60	75
<i>Glochidion</i> sp.	70	65
<i>Hemidesmus indicus</i>	5	..
<i>Ixora coccinea</i>	80	90
<i>Ixora brachiata</i>	..	15
<i>Jasminum malabaricum</i>	10	..
<i>Lantana camara</i>	70	35
<i>Osyris wightiana</i>	10	5
<i>Olea dioica</i>	10	5
<i>Randia brandisii</i>	40	..
<i>Santalum album</i>	5	..
<i>Syzygium caryophyllatum</i>	90	50
<i>Syzygium cumini</i>	25	25
<i>Tabernaemontana heyneana</i>	5	..
<i>Terminalia chebula</i>	5	5

The chief components of this scrub are *Syzygium caryophyllatum*, *Ixora coccinea*, *Glochidion* sp., *Gardenia gummifera*. Other shrubs present are: *Bridelia stipularis*, *Carissa congesta*, *Randia brandisii*, with species like *Syzygium cumini*, *Canthium dicoccum*, *Flacourtia montana*, *Tabernaemontana heyneana*, *Terminalia chebula* and *Olea dioica*.

Dalbergia sympathetica, *Celastrus paniculata*, *Hemidesmus indicus*, are the chief climbers noted in the forest.

Seedlings of *Vitex altissima* and *Carallia brachiata* are often seen on the forest ground.

Syzygium-Gardenia-Ixora type (Table VI) has been studied in the near surroundings of the above type but along the base of low hillocks. This type too is developed on laterite, and has more of evergreen components like *Garcenia tinctoria*, *Leea indica*, *Ficus* spp., *Carvia*, *Carallia brachiata*, *Ixora brachiata*, *Psychotria truncata* with *Pothos scandens*. Rest of the vegetation was like that of the above community with species of *Gardenia*, *Syzygium*, *Ixora* and others.

This type may develop into a forest of *Terminalia-Syzygium-Careya* type; but anyway, the trend is towards an evergreen climax.

COASTAL SCRUB

The coastal scrub is confined to the west of the district. The soil on which it is developed is hard, dry laterite, exposed, denuded and

TABLE VI
Syzygium-Gardenia-Ixora Type

Date	22-3-1959
Locality	Minor forest, Siddapur
Aspect	Low hilly area
Geology	Laterite, rock exposed at places
Soil	Red
No. of quadrats studied ..	20

Name of the plant	% Occurrence
<i>Bridelia stipularis</i>	15
<i>Buchanania lanzan</i>	5
<i>Canthium dicoccum</i>	10
<i>Carissa congesta</i>	40
<i>Careya arborea</i>	50
<i>Celastrus paniculata</i>	5
<i>Cyclea peltata</i>	5
<i>Dalbergia sympathetica</i>	20
<i>Flacourtia indica</i>	30
<i>Flacourtia montana</i>	5
<i>Gardenia gummiifera</i>	70
<i>Glochidion</i> sp.	40
<i>Ixora coccinea</i>	70
<i>Jasminum malabaricum</i>	35
<i>Lantana camara</i>	30
<i>Olea dioica</i>	5
<i>Osyris wightiana</i>	25
<i>Randia brandisii</i>	50
<i>Syzygium caryophyllatum</i>	70
<i>Syzygium cumini</i>	40
<i>Terminalia chebula</i>	10
<i>Zizyphus rugosa</i>	20

hardened by biotic interferences. *Acacia sundra* dominates at some places near Karwar. At Katgal-Kumta, *Ixora coccinea*, *Syzygium*, and other evergreen species are more common while on heavily grazed places near habitations, some dry deciduous species may be seen.

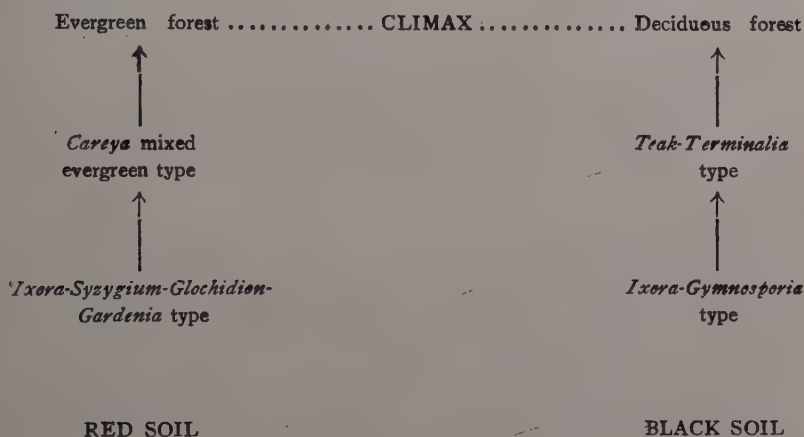
The main constituents are *Gardenia gummiifera*, *Randia brandisii*, *Ixora* sp., *Leea indica*, *Psychotria*, with a good growth of grasses like

Ischaemum, *Eulalia*, *Heteropogon contortus*. Saplings of *Syzygium cumini* and *Terminalia tomentosa* are also met with.

The composition is similar to that of laterite scrub studied along Sirsi-Siddapur plateau and shows a trend towards an evergreen climax. However *Acacia sundra* has not been observed in the scrub forest near Siddapur.

DISCUSSION

The various communities described above are mainly biotic/bioedaphic types and belong to two distinct series. one growing on black soil and the other on red soil. Their successional status is indicated below. Much of discussion about these two types with regard to their relationships on soil basis cannot be indicated at the moment and will be presented later on when soil studies on these distinct types have been completed.



(Biotic/Bioedaphic types)

Succession in Scrub Forests of N. Kanara

SUMMARY

The situation, topography, geology, and climate of North Kanara district are presented. Of the three vegetation types, viz., scrubs, deciduous forests and evergreen forests, only the scrubs are described in this paper. The successional status of the various communities studied has also been indicated.

ACKNOWLEDGEMENTS

The author is grateful to Dr. G. S. Puri for the necessary guidance given during these studies. He is also thankful to Shri S. K. Jain for having gone through the paper. Thanks are also due to C.S.I.R. body for the award of Junior Research Fellowship during the period of the studies.

REFERENCES

- COELHO, F. A. B. 1956. *Revised Working Plan for the High Forests—Block I-XX of North Kanara Division*. Bombay Government Press.
- DAVIS, H. P. W. 1927. *Revised Working Plan Report of the High Forests—Old Series I-VII of the Kanara Northern Division*. Bombay Government Press.
- DHANESHWAR, S. S. 1939. Honavar range and teak regeneration. *Indian For.* 65: 406-24.
- . 1941. The denuded condition of the minor forest in Kanara coastal tract. *Ibid.* 67: 68-81.
- KAIKANI, N. S. 1945. *Revised Working Plan for the Gund Forests, North Kanara*. Bombay Government Press.
- KESARCODI, S. N. 1932. *Working Plan for the Sandal Forests of Dharwar-Bijapur, and of Haliyal and Mungod Ranges of Northern and Eastern Kanara Divisions Respectively*. Bombay Government Press.
- MAVIN KARVE, N. S. 1955. *Revised Working Plan for the Ramangali and Ankola Forests, North Kanara*. Bombay Government Press.
- MIRCHANDANI, T. K. 1941. Kanara forests. *Indian For.* 67: 62-68.
- SANTAPAU, H. 1955. A botanical excursion to North Kanara, Bombay State, in May 1954. *J. Bombay nat. Hist. Soc.*, 53: 10-28.

FURTHER CONTRIBUTIONS TO OUR KNOWLEDGE OF *ISOETES* SAMPATHKUMARANI RAO, L. N.

Part III. Shoot Apex

BY USHA SHARMA

Lucknow University, Lucknow

(Received for publication on November 17, 1959)

THE morphology and anatomy of the vegetative parts of *Isoetes sampathkumarani*, its megasporogenesis and some stages of germination have already been studied (Sharma, 1958 and 1959).

The present paper in the same series records some observation about the shoot apex of this species.

MATERIAL AND METHODS

The material studied was the same that was used in the earlier studies. It includes young and old plants collected between the months, June–November. Microtome sections varying from 6μ to 12μ in thickness were helpful. The staining was mostly done with Haemoe-toxylin and Orange G.

HISTORY

A detailed historical account of the apical meristem in *Isoetes* has already been given by Scott and Hill (1900, p. 418) working on *Isoetes hystrix*. Bhambie (1957, pp. 492–94) has also discussed this at length in connection with his study of the shoot apex of *Isoetes coromandelina*, L.

The various views of the organisation of the shoot apex in *Isoetes* fall under two main categories. One supposes that a single apical cell is involved. This view is supported amongst others by Hofmeister (1862) and Van Tieghem (1891, p. 1429). Scott and Hill are also of the same opinion. They observed a pair of large cells in the central apical region of the stem of *Isoetes hystrix* (Scott and Hill, p. 418, pl. 23, Fig. 1). The larger of the two cells is somewhat triangular and has a large nucleus. This is regarded by them as the apical cell. The other is supposed to have been cut off from this.

A second view is that a group of cells constitute the apical meristem. Hegelmaier (1874, p. 497) working on *I. velata* and *I. duriacii* reached the conclusion that there is an *apical cell surface* constituting the apical meristem. Bruchmann (1874, p. 570) and Farmer (1890, p. 39), who

have worked on *Isoetes lacustris*, also support this view. The observations of Campbell (1891, p. 245) on *I. echinospora*, Smith (1900, p. 288) on *I. engelmanni* and *I. echinospora* and West and Takeda (1915) on *I. japonica* show a group of cells in the apical region of the stem.

There are four known species of *Isoetes* in India but the morphology of the shoot apex of only one species, i.e., *Isoetes coromandelina* has been worked out by Bhambie (*loc. cit.*, pp. 491-502). His observations show that the initiation of the stem takes place by a group of cells and not a single one. This group of cells, which are 2 or 3 cells deep in very young stages, gradually form a mound which can be distinguished into a superficial epidermal layer dividing by anticlinal divisions and an inner mass of cells dividing irregularly. These constitute the real shoot apex.

OBSERVATIONS

In the present paper similar studies have been carried out on *Isoetes sampathkumaranii* and it may be stated at the very beginning that the shoot apex is formed on almost the same lines as in *Isoetes coromandelina*.

Observations were based on both longitudinal as well as transverse sections of young and old plants.

It is significant that a single apical cell has not been observed in any of the sections examined. All the stages of shoot apex development show that the apex is constituted by a group of meristematic cells as in *I. coromandelina* (Bhambie, 1957).

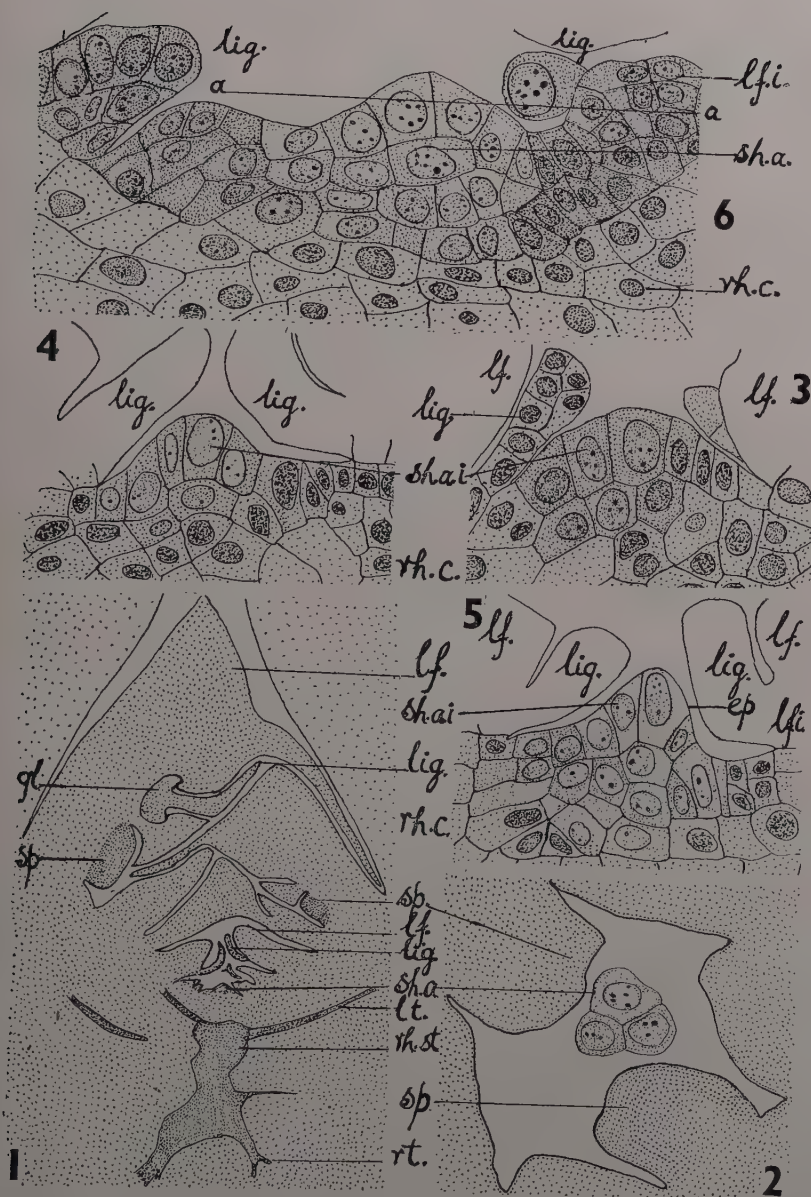
Text-Figure 1 is a median vertical longitudinal section of an old plant passing through the region of the shoot apex. The apical meristem (*sh.a*) is indicated in the figure. It can be seen as a small elevation or mound of tissue. Text-Figure 2 is a transverse section taken at the highest level of this mound of tissue. Such a section always shows a group of 3 cells.

Text-Figure 3 is the earliest stage seen in the formation of this dome-shaped meristem. It shows three centrally placed, densely cytoplasmic, prominent cells (*sh.a.i.*) with very big nuclei. The nuclei contain rich but faintly staining cytoplasm and three to six big nucleolei. The other surrounding cells have nuclei containing dark staining cytoplasm.

Text-Figure 4 is a later stage. The cells have now multiplied into six or seven, the peripheral ones show clearly anticlinal divisions.

Text-Figure 5 is still further advanced stage. It shows more or less 13 or 14 meristematic cells. The epidermal layer (*ep.*) is raised higher at this stage and becomes dome-shaped.

Text-Figure 6 and Plate V, Fig. 1 are vertical longitudinal sections of a still older plant at a stage shown in Text-Fig. 1. The mass of lightly shaded cells represent the shoot apex (*sh.a.*) The mass of darkly shaded cells on both sides represent meristems of young leaves. The bigger



TEXT-FIGS. 1-6. Fig. 1. Median vertical longitudinal section of an old plant passing through the region of the shoot apex. Fig. 2. Transverse section of the rhizomorph taken at the highest level of the shoot apex consisting of three cells. The sporangia of neighbouring sporophylls are seen. Fig. 3. Shows a group of 3 large cells with big nuclei the shoot apex initials. Fig. 4. The shoot apex initials have increased in number and one of them appears to have recently divided. Fig. 5. The shoot apex initials have now further divided to form a three-layered tissue. The

uppermost layer is raised into a short dome. On the right-hand side of this dome can be seen the leaf initials. The neighbouring leaves and their ligules are seen. Fig. 6. The shoot apex initials have now spread out further and become a flattened 4 cells deep layer. Leaf initials can be seen on both sides of shoot apex. (Fig. 1, $\times 60$; rest $\times 643$); *ep.*, epidermal layer; *gl.*, glossopodium; *lf.*, leaf; *lf.i.*, leaf initials; *lig.*, ligule; *l.t.*, leaftrace; *rh.c.*, rhizomorph cells; *rh.st.*, rhizomorph stele; *r.t.*, root trace; *sp.*, sporangium; *sh.a.*, shoot apex; *sh.a.i.*, shoot apex initials; *a-a* is the line along which a transverse section would pass to give the appearance shown in Fig. 2.

cells lower down, with darkly staining, small nuclei and very little cytoplasm, are the cells of the rhizomorph. It can be noted that the meristematic cells have increased considerably in number and the dome-shape of the tissue has been flattened down as also happens in *Isoetes coromandelina* (Bhambie, *loc. cit.*, p. 494).

Transverse sections confirm the interpretations expressed above. Text-Figure 2 is a transverse section of a shoot apex passing at a level *a-a* in Text-Fig. 5. It shows a group of three cells. The very next transverse section (Plate V, Fig. 2) shows a number of meristematic cells. Since the sections are not more than 15μ thick it shows that the meristem is not more than 3 or 4 cells deep and that the dome is broad and not high. In case of *Isoetes coromandelina* this meristematic dome is very much taller and more broad-based. This is quite understandable because the rhizomorph of *I. coromandelina* is bigger, more robust and also three-lobed. It is but natural that the meristematic mound should be smaller and less broad-based in the comparatively smaller and two-lobed *I. sampathkumaranii*.

SUMMARY

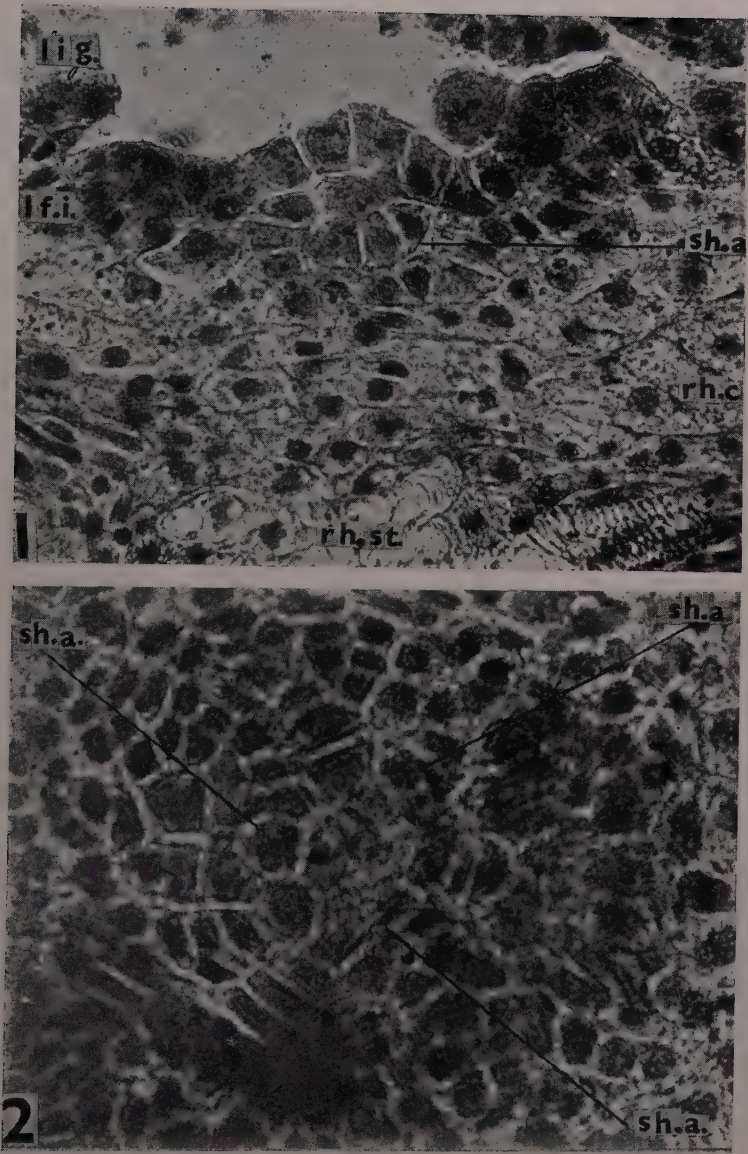
Two different views have been expressed in the past regarding the shoot apex of *Isoetes*. According to one the shoot apex arises from a single apical cell. The other view regards that a group of cells from the meristem of the shoot apex. It has been found in *I. sampathkumaranii* that a group of cells differentiate into an outer epidermal layer dividing mostly by anticlinal walls and an inner mass of cells dividing irregularly. This entire tissue is the initial shoot apex in this species of *Isoetes*.

ACKNOWLEDGEMENTS

The author is highly grateful to Dr. A. R. Rao, for his valuable guidance and critical suggestions during the course of this investigation.

REFERENCES

- BHAMBIE, S. 1957. Studies in Pteridophytes, I. The shoot apex of *Isoetes coromandelina*, L. *J. Indian Bot. Soc.* **36**: 491-502.
- * BRUCHMANN, H. 1874. Ueber Anlage und Wachstum der Wurzeln von *Lycopodium* und *Isoetes*. *Jena. Z. Naturw.* **8**:
- CAMPBELL, D. H. 1891. Contributions to the life-history of *Isoetes*. *Ann. Bot., Lond.* **5**: 231-58.



Usha Sharma

FIGS. 1-2

- DEBARY, A. 1884. *Comparative Anatomy of the Phanerogams and Ferns*. English Translation, Oxford.
- FARMER, J. B. 1890. On *Isoetes lacustris*. *Ann. Bot., Lond.* 5: 37-62.
- * HEGELMAIER, F. 1874. Zur Kenntniss einiger *Lycopodinen*. *Bot. Z.* 32:
- HOEHEMEISTER, W. 1862. *The Higher Cryptogamia*. Roy. Soc. London.
- SCOTT, D. H. AND HILL, T. G. 1900. The structure of *Isoetes hystrix*. *Ann. Bot. Lond.* 14: 413-54.
- SHARMA, U. 1958. Contributions to our knowledge of *Isoetes sampathkumarani* Rao, L. N. Pt. I. Vegetative parts. *Proc. Indian Acad. Sci.* 47 B: 210-24.
- . 1959. Further contributions to our knowledge of *Isoetes sampathkumarani* Rao, L. N. Pt. II. Megasporogenesis and some stages of germination. *Proc. Indian Acad. Sci.* 50 B: 319-339.
- SMITH, R. W. 1900. The structure and development of *Isoetes*. *Bot. Gaz.* 29: 225-50; 323-46.
- TIEGHEM, VAN P.H. 1891. *Traite de Botanique*, Ed. 2.
- * WEST, C. AND TAKEDA, H. 1915. On *Isoetes japonica*. *Trans. Linn. Soc. Lond., (Bot.)* 8: 331-76.
- * Papers marked with an asterisk have not been seen by the author.

EXPLANATION OF PLATE V

- FIG. 1. A photograph of the section shown in Fig. 6.
- FIG. 2. A horizontal section running through the middle region of the meristematic pyramid. Abbreviations same as in Text-Figs. (Fig. 1, $\times 526$; Fig. 2, $\times 612$).

STUDIES IN THE ANNONACEAE

II. The Development of Ovule and Seed in *Cananga odorata* and *Milium wightiana*

BY K. PERIASAMY AND B. G. L. SWAMY

Department of Botany, Presidency College, Madras-5, India

(Received for publication on December 3, 1959)

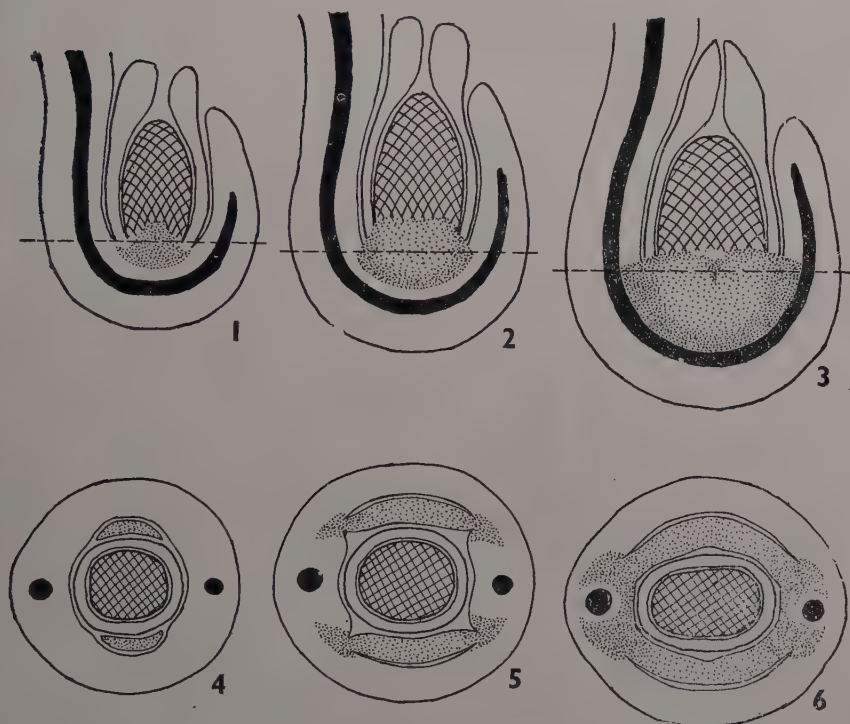
A BRIEF account of the previous embryological literature of the Annonaceae has been given in the first paper of this series (Periasamy and Swamy, 1959). The present study gives a detailed account of the development of ovule, seed and rumination in two members of the family. Microtechnical methods are the same as previously described (Periasamy and Swamy, 1959).

OBSERVATIONS

Ovule.—The carpels of *Cananga odorata* as well as of *Milium wightiana* are typically conduplicate. The placental ridges develop from the morphologically adaxial laminar surface. In *Cananga odorata*, the ovules are vascularized by the branches arising from the dorsal bundle (Periasamy and Swamy, 1956).

The primordium of the ovule differentiates from the tip of the placental ridge. To begin with, the young nucellus is covered over by two integuments which correspond to the conventional inner and outer integuments, both of which originate more or less simultaneously (Text-Fig. 7). However, the inner one grows at a faster rate and its free edge projects beyond the outer to inclose a narrow micropylar canal (Text-Figs. 3, 10). The basal portion of the inner integument, as far as it is covered over by the outer, is only two cell-layered or occasionally three-layered (Text-Fig. 10). The outer integument consists of four or five layers of cells (Text-Fig. 10) and does not grow much beyond the height of the nucellus (Text-Figs. 1-3, 10).

An unusual feature of *Cananga odorata* is the development of a middle integument in between the inner and outer integuments at the time of megasporogenesis (Text-Fig. 10). The middle integument arises in the transmedian longitudinal plane of the ovule as two discontinuous strips from two separate groups of meristematic cells which differentiate in the chalazal region on either side of the vascular trace (Text-Figs. 1, 4, 10). To begin with, the meristems function at the chalazal region, but, as development proceeds, there is a widening out of the meristems towards the raphe and the antiraphe so as to establish connection with the inner face of the outer integument on either side of the vascular trace (Text-Figs. 2, 3, 5, 6). After this, the micropylar

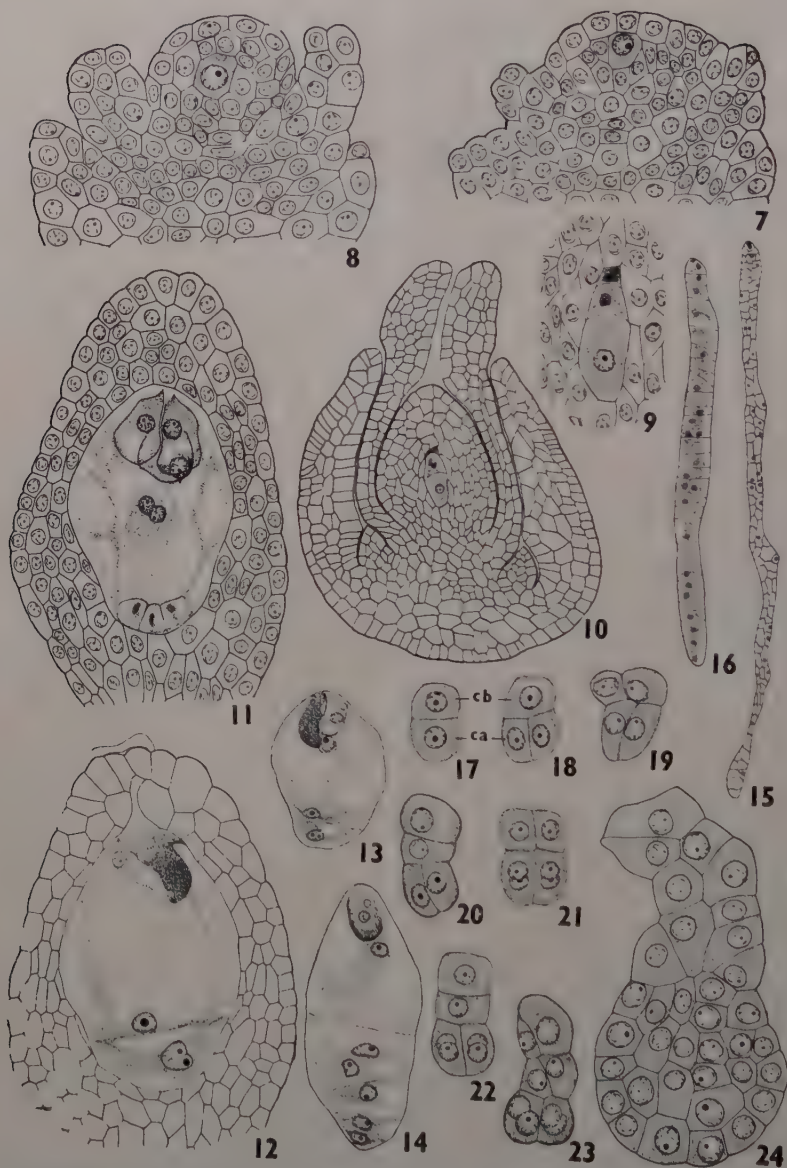


TEXT-FIGS. 1-6. *Cananga odorata*. Series of semi-diagrammatic sketches conveying the features in the origin and development of the middle integument from its inception up to the time of fertilization. Figs. 1-3. Sagittal, median longitudinal sections. Figs. 4-6. Transverse sections at levels marked by broken lines in Figs. 1-3 respectively. Sparsely stippled areas represent the middle integument and the densely stippled areas the meristematic region; nucellus cross-hatched; thick black area indicates vascular trace.

portion of the middle integument develops mainly as lateral extensions of the outer integument. These extensions meet along the transmedian line and fuse together (Text-Fig. 3).

Because of its discontinuous origin and development in the micropylar region as lateral extensions of the outer integument, the middle integument never becomes an annular structure at any level of the ovule (Text-Figs. 5, 6) or in the seed. The vascular trace of the ovule does not end at the chalaza, but extends on the antiraphe side up to the tip of the outer integument (Text-Fig. 3).

Female gametophyte.—The single hypodermal archesporial cell differentiates simultaneously with the origin of the integuments (Text-Fig. 7). It divides into a primary parietal cell and a primary sporogenous cell. The primary parietal cell divides anticlinally (Text-Fig. 8) and



TEXT-FIGS. 7-15 AND 17-24. *Cananga odorata*. TEXT-FIG. 16. *Miliusa wightiana*. Fig. 7. L.s. of ovule showing hypodermal archesporial cell and origin of integuments. Fig. 8. Same as Fig. 7, later stage showing young megaspore mother cell and parietal cells. Fig. 9. Linear tetrad, the three micropylar megaspores degenerating. Fig. 10. Transmedian l.s. of the ovule just after the initiation of the middle integument. Fig. 11. Mature embryo-sac. Fig. 12. L.s. of two-celled endosperm and nucellus. Fig. 13. L.s. of three-celled endosperm. Fig. 14. L.s. of young endosperm showing linear series of cells with a larger micropylar one,

Fig. 15. L.s. of endosperm before lateral expansion. Fig. 16. L.s. of endosperm of uniseriate cells. Text-Figs. 17-24. Stages in embryogenesis. Figs. 7-9, 17-24, $\times 520$; Figs. 10, 13, 14, $\times 230$. Figs. 11, 12, $\times 400$. Fig. 15, $\times 29$. Fig. 16, $\times 58$.

periclinally to produce a massive parietal tissue (Text-Figs. 10, 11). The primary sporogenous cell functions as the megaspore mother cell. The embryo-sac develops according to the Polygonum type (Text-Figs. 9-11). The egg apparatus has typical organization, but the antipodals degenerate before fertilization (Text-Fig. 11). The polar nuclei do not fuse, but lie in contact with each other in the centre of the embryo-sac (Text-Fig. 11).

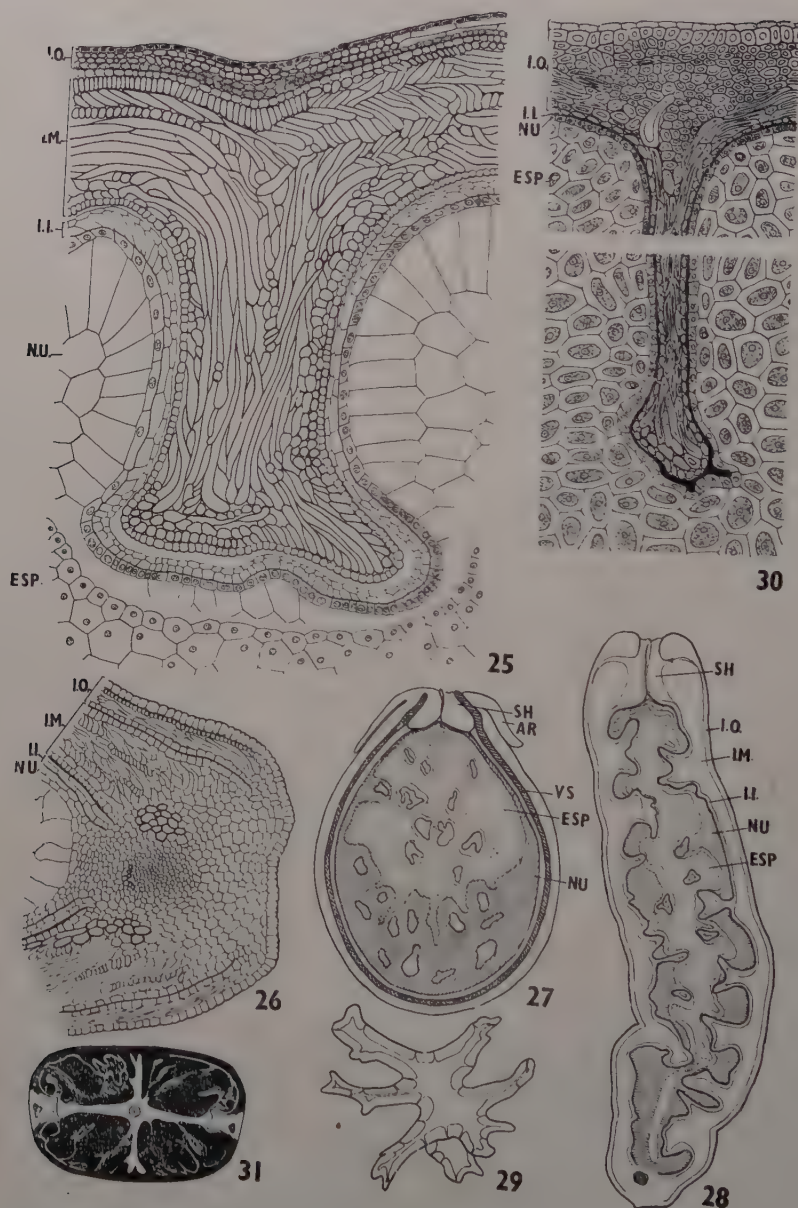
Fruit wall.—The first obvious exomorphic change following successful fertilization is the marked intercalary elongation of the short solid stipe of the carpel. Thus, the almost sessile carpels get themselves lifted up on stipes of more than two centimetres length.

At the time of fertilization, the ovary wall consists of three zones: an outermost and an innermost zone of essentially parenchymatous cells, and a middle zone traversed by vasculature. After fertilization, the cells of the inner zone become actively meristematic and bring about a marked increase in the thickness of the carpel wall and an ingrowth of the tissue in the form of folds and projections (Plate VI, Fig. 1). The ingrowth ultimately surrounds the ovules which become separated from each other due to rapid elongation of the carpel.

The outermost zone of the carpel wall does not show such a marked meristematic activity like the inner, but gradually attains an increasingly tough and coriaceous texture. A conspicuous development of sclereids takes place in the inner zone and in the vascular zone. The secondary wall of the sclereids becomes heavily lignified with numerous simple pits (Text-Fig. 29).

Seed.—In *Cananga odorata*, the meristem of the middle integument remains dormant *in situ* in the mature ovule and resumes its activity immediately after fertilization. The two zones, flanking the vascular loop on either side at the chalazal part, first establish connection with each other across the vascular bundle so as to become a single continuous zone around the vascular trace (Text-Fig. 26). Further activity in this U-shaped meristematic zone is more marked along the base rather than at the arms. Thus, the zone widens out centrifugally towards the base, producing new tissues mainly along the median longitudinal plane.

The tissues produced centripetally by the meristem are added on to the three integuments and the nucellus (Text-Fig. 26). Therefore, the entire meristematic zone behaves in a manner essentially similar to the chalaza, which, however, instead of being confined to the base, as in other seeds, extends all around the seed along the median plane. The seeds are thus perichalazal (Corner, 1949), and the integuments do not have an annular configuration in those regions where the perichalaza extends. Since increase in dimension takes place mainly along the median and very little along the transmedian longitudinal plane, the seeds become flattened along the median plane (Text-Fig. 28).



TEXT-FIGS. 25-29. *Cananga odorata*. TEXT-FIGS. 30-31. *Miliusa wightiana*.
 Fig. 25. Fully formed ruminational process with nucellar remains and endosperm in the immature seed. Fig. 26. The region of perichalazal meristem as seen in l.s. of seed at the time of origin of ruminational. Fig. 27. Median l.s. of seed at the time when endosperm expands rapidly. Fig. 28. Transmedian l.s. of seed similar to that

in Fig. 27. Fig. 29. A sclereid of the inner region of the fruit wall. Fig. 30. Seed coat, rumination ingrowth and endosperm as seen in l.s. of mature seed. Fig. 31. Fully formed rumination plates in t.s. of seed; note cylindric endosperm in the centre. Figs. 25, 26, 29, $\times 110$. Fig. 27, $\times 6$, Fig. 28, $\times 12$. Fig. 30, $\times 175$; Fig. 31, $\times 5$; AR—Aril; ESP—Endosperm; II—Inner integument; IM—Middle integument; IO—Outer integument; NU—Nucellus; SH—Subhilar tissue; VS—Vascular strand.

The development of seedcoat and rumination (Text-Fig. 25) has been described by Corner (1949), and there is nothing more to be added to his account.

In *Miliusa wightiana*, the perichalazal post-fertilization increase in the dimensions of the seed does not take place only along the median longitudinal plane as in *Cananga*, but along the transmedian longitudinal plane as well. Hence, the seeds are not flat (Text-Fig. 31, Plate VI, Fig. 4) but may become slightly compressed against each other in the mature fruit.

The rumination ingrowths develop from the outer integument (Text-Fig. 30) which becomes more massive than the outer integument of *Cananga*. The cells of the outer integument except the innermost layer become heavily lignified. Fibre-like elongation of the cells takes place mainly in the four or five layers bordering upon the unthickened innermost layer (Text-Fig. 30). The inner integument becomes completely crushed.

In the mature seed, the rumination ingrowths are arranged in a somewhat regular pattern. They are uniformly plate-like and extend centripetally at nearly regular intervals and at right angles to the vertical axis of the seed (Plate VI, Fig. 4). Occasionally the plates show bifurcation and anastomoses with the neighbours (Plate VI, Fig. 4). The rumination ingrowths do not constitute unbroken transverse plates all around the inner face of the seed, but are conspicuously absent along the median and transmedian longitudinal planes. Thus, as seen in transverse sections, the rumination ingrowths are confined to the four sectors of the seed, the sectors conforming to bilateral symmetry (Text-Fig. 31). The perichalazal region and the vascular strand which traverses through it become pushed into the seed cavity along the median longitudinal plane (Text-Fig. 31; Plate VI, Fig. 4).

Nucellus.—The nucellus increases enormously after fertilization. This is accomplished in two ways: (i) by the activity of the perichalazal meristem which produces new nucellar tissue in a centripetal manner; during the initial stages, the activity is more evidently seen in the chalazal part (Plate VI, Fig. 3); (ii) by periclinal divisions of the outermost layer of cells of the nucellus.

The production of new nucellar tissue continues until the initiation of rumination. After cessation of meristematic activity, the inner cells of the nucellus enlarge first, leaving the outermost two layers *in situ* (Text-Fig. 26). Of these two layers, later on, the inner one undergoes considerable enlargement (Text-Fig. 25). During this process, a majority of the centrally situated cells become disorganized (Text-Fig. 25; Plate I,

Fig. 4). The outermost layer persists without any change for a still longer time even in the mature seed in *Miliusa wightiana* (Text-Fig. 30), but in *Cananga odorata* this layer also becomes finally replaced by the endosperm (Plate VI, Fig. 2).

Endosperm.—Immediately after triple fusion, the primary endosperm nucleus moves towards the chalazal end of the embryo-sac and divides to form a smaller chalazal cell and a larger micropylar cell (Text-Fig. 12). Of these, the micropylar cell does not divide for some time, but divisions take place in the chalazal cell, in the same plane as the first division (Text-Figs. 13, 14). In *Cananga odorata*, about 20 superposed cells, and in *Miliusa wightiana* more than 30 cells (Text-Figs. 16; Plate VI, Fig. 3) are formed before divisions in other planes are initiated. The subsequent divisions take place in all these cells in varied planes to give rise to a longitudinally stretched endosperm tissue which becomes irregularly lobed in *Cananga odorata* (Text-Fig. 15), but retains its cylindric shape in *Miliusa wightiana* (Text-Fig. 31). The tissue then enlarges digesting the surrounding nucellar cells, first at places confronting the rumination ingrowths and finally by penetrating in between them (Text-Figs. 25, 27, 28; Plate VI, Fig. 4). Eventually, the whole tissue becomes very compact, relatively thick-walled, and densely packed with darkly-staining fatty or lipoidal compounds (Text-Fig. 30; Plate VI, Fig. 2).

Embryo.—Embryo development was followed in *Cananga odorata* only. The division of the zygote is postponed until the endosperm begins to expand laterally. The first division is transverse resulting in terminal and basal cells, *ca* and *cb* respectively (Text-Fig. 17). The second division takes place in *ca* by a vertical wall (Text-Fig. 18). The cell *cb* divides either transversely or vertically (Text-Figs. 19, 20), while the derivatives of *ca* undergo another division in the same plane as the first division, to produce the quadrant (Text-Figs. 21–23). The derivatives of the quadrant contribute a major share to the mature embryo; those of the basal cell develop into a massive suspensor, and also take part in the construction of the embryo proper (Text-Fig. 24). Thus the development conforms to the lotus-variation of Onagrad type (Johansen, 1950).

DISCUSSION

Embryo-sac.—In 1914, Oes reported a subhypodermal origin of the archesporial cell in *Cananga odorata*. According to him, the archesporial cell usually differentiates in the fourth layer of the nucellus and functions directly as the megaspore mother cell. Schnarf (1931) observes that the report of Oes is incorrect in view of the well-established hypodermal origin of the archesporial cell in *Annona cherimolia*, *Asimina triloba*, *Annona montana*, *Orophea hexandra*, *Unona dasymoschala* and *Cananga odorata*. Schnarf also remarks that the archesporial cell divides to give rise to a parietal cell in all these plants. Juliano (1935) asserts that in *Annona muricata* and *A. squamosa*, the archesporial cell directly functions as the megaspore mother cell, without giving

rise to a parietal cell. Lampton (1957) also reports subhypodermal origin of the archesporial cell in *Asimina triloba*, and contradicts the observation of Herms (1907). In the two species investigated at present the archesporial cell is of hypodermal origin and divides to form a parietal cell and a sporogenous cell. These conflicting reports necessitate a thorough investigation of a large number of plants of the Annonaceae with regard to the place of origin of the archesporial cell.

The embryo-sac develops according to the Polygonum type as also in other investigated members of the family. Leopoldine Stark—as reported by Schnarf (1931)—records the presence of starch grains in the embryo-sac of *Cananga odorata*. This feature is, however, absent in the material of the same species investigated at present and also in *Miliusa wightiana*; the other representatives of the family that have been investigated also fail to record this feature.

Seed.—The seed structure of *Cananga odorata* has been described by Corner (1949). The study demonstrates that the middle integument is not an entirely post-fertilization development as Corner assumes, but arises at about the time of sporogenesis in the ovule. It has a peculiar development as mainly lateral extensions of the outer integument in the micropylar region. In all the annonaceous seeds (Corner, 1949), the chalaza, instead of confining itself to the basal part of the seed (that is, antimicropylar part of the anatropous seed), becomes extended during post-fertilization development along the median longitudinal plane, thereby losing its radial symmetry and acquiring a bilateral symmetry. Corner designates this as the *perichalaza*, and the seeds as *perichalazal*. Growth of the chalaza, leading to a perichalaza or to an overall increase of the chalazal region as a massive tissue during post-fertilization development, appears to be characteristic of many seeds with ruminant endosperm occurring in diverse families of the angiosperms (Periasamy, 1961 a, b).

The phenomenon of rumination in the Annonaceae has been studied by Voigt (1888) and Corner (1949). Corner considers the rumination processes as infoldings caused by excessive growth of the integuments.

The integuments which constitute the rumination ingrowths varies in different plants of the Annonaceae. The outer integument and the inner integument constitute the rumination ingrowths in *Alphonsea sceramensi*, *Annona reticulata*, *A. squamosa*, *Artabotrys blumei*, *Maladorum bankanum*, *M. latifolium*, *Uvaria lowii* (Voigt, 1888), *Alphonsea elliptica*, *Annona muricata*, *Artabotrys odoratissimus*, *Desmos chinensis*, *D. dumosa*, *D. dasymaschala*, *Popowia nervosa*, *P. tomentosa*, *Xylopia caudata*, *X. fusca*, *X. malayana* (Corner, 1949), and *Miliusa wightiana*. In *Anaxagorea javanica* (Corner, 1949), the rumination ingrowths are formed by the inner integument alone. In *Polyalthia purpurea* (Corner, 1949) the rumination is brought about by the inner integument, but the outer integument extends into the base of the large plates. Plants which possess a middle integument are *Cananga odorata*, *Mezettia leptapoda* and *Xylopia curtisii* (Corner, 1949); in these, the rumination

ingrowths are composed of the middle integument and the inner integument.

The shape and arrangement of the rumination ingrowths are very variable in the Annonaceae. They may either be thick, hump-like projections as in *Cananga* or thin plate-like extensions as in *Milium*. In the former case, the arrangement is irregular without any definite pattern while in the latter, the ingrowths conform to a regular alignment. Thus, in *Uvaria lowii*, *Alphonsea ceramensis*, *Artabotrys blumei*, *Desmos dasymaschala* (Voigt, 1888) Corner, 1949; and *Milium wightiana* they are arranged in four regular longitudinal rows, one over the other.

Nucellus.—The persistence of the outermost layer of the nucellus, as seen in *Milium wightiana*, is a feature also shared by *Anaxagorea javanica*, *Desmos chinensis* and *D. dumosa* (Corner, 1949). Some of the persisting cells of the nucellus become transformed into oil cells in *Annona squamosa*, *Desmos chinensis*, *D. dasymaschala*, and *D. dumosa* (Corner, 1949).

Endosperm.—The endosperm is *ab initio* cellular in all the investigated plants of the Annonaceae. The first few divisions of the primary endosperm nucleus result in a single row of varying number of cells in all the representatives studied (Herms, 1907; Schnarf, 1931). At a later stage, the endosperm becomes a slender longitudinally stretched tissue. In *Milium wightiana*, the endosperm is extensive from the micropylar to the chalazal end of the young seed, before beginning to increase in lateral dimensions. But in *Cananga odorata*, lateral growth is not preceded by longitudinal growth to the same degree as in *Milium*.

Embryo.—The embryogeny of only three members have so far been studied in the Annonaceae. In *Polyalthia longifolia* (Sastri, 1954), embryo development follows the Trifolium variation of Onagrad type. In *Cananga odorata* also the embryo develops according to the Onagrad type, but follows the Lotus variation (Johansen, 1950). The observations of Herms (1907) on the embryo development in *Asimina triloba* are casual, and he remarks that divisions from the second cell generation are irregular.

SUMMARY

The ovule of *Cananga odorata* is bitegmic during initial stages, but a middle integument arises during megasporogenesis between the two integuments, on wither of the vascular trace at the chalazal region. The middle integument does not develop in an annular manner; during later stages of ontogeny, its development in the micropylar region takes place mainly as lateral extensions of the outer integument. In *Milium wightiana* the ovules are bitegmic throughout and no middle integument develops. In both these plants, the vascular trace of the ovule extends on to the antiraphe side up to the tip of the outer integument.

The embryo-sac develops according to the Polygonum type. The antipodals are ephemeral,

The inner region of the carpel wall becomes meristematic during post-fertilization stages and fills the locule in the form of a spongy tissue.

Post-fertilization development of the seed is mainly due to a unique perichalazal meristem which functions around the vascular trace and encircles the seed along the median longitudinal plane. In *Cananga odorata*, the rumination ingrowths are constituted by the inner integuments and the middle integument; in *Miliusa wightiana*, by the inner integument and the outer integument. The rumination ingrowths are plate-like and arranged in a somewhat regular pattern in the latter plant.

The endosperm is *ab initio* cellular and extends to considerable longitudinal dimensions before expanding laterally. It absorbs the nucellar tissue developed during post-fertilization, grows in between the rumination processes, and fills the seed.

In *Cananga odorata*, embryo development follows the Lotus variation of the Onagrad type.

REFERENCES

- CORNER, E. J. H. 1949. The anonaceous seed and its four integuments. *New Phytol.* **48**: 332-64.
- HERMS, W. B. 1907. Contribution to the life-history of *Asimina triloba*. *Ohio-Nat.* **8**: 211-15.
- JOHANSEN, D. A. 1950. *Plant Embryology*. Chronica Botanica, Mass., U.S.A.
- JULIANO, J. B. 1935. Morphological contributions on the genus *Anona* Linn. *Phlipp. Agric.* **24**: 528-41.
- LAMPTON, R. K. 1957. Floral morphology in *Asimina triloba* Dunal, I. Development of the ovule and embryo-sac. *Bull. Torrey bot. Cl.* **84**: 151-56.
- * OES, A. 1914. Beiträge zur Entwicklungsgeschichte der Annonaceen. *Verh. naturf. Ges. Basel* **25**: 168-78.
- PERIASAMY, K. 1961 a. Studies on reeds with ruminant endosperm-1. Morphology of ruminating tissue in *Ministica tragnons*. *J. Univ. Madras* (In press).
- 1961 b. The numinate endosperm. 1. Development and types rumination. *Phytomorphology* (In press).
- AND SWAMY, B. G. L. 1956. The conduplicate carpel of *Cananga odorata*. *J. Arnold Arb.* **37**: 366-72.
- . 1959. Studies in the Annonaceae. I. Microsporogenesis in *Cananga odorata* and *Miliusa wightiana*. *Phytomorphology* **9**: 251-263.
- SASTRI, R. L. N. 1954. Development of the embryo of *Polyalthia longifolia* Hook. f. and Thoms. *Curr. Sci.* **24**: 51.
- SCHNARF, K. 1931. *Vergleichende Embryologie der Angiospermen*. Berlin.
- VOIGT, A. 1888. Untersuchungen über Bau und Entwicklung von Samen mit ruminertum Endosperm aus den Familien der Palmen, Myristicaceen und Anonaceen. *Ann. Jard. bot. Buitenz* **7**: 150-90.

* Not seen in the original.

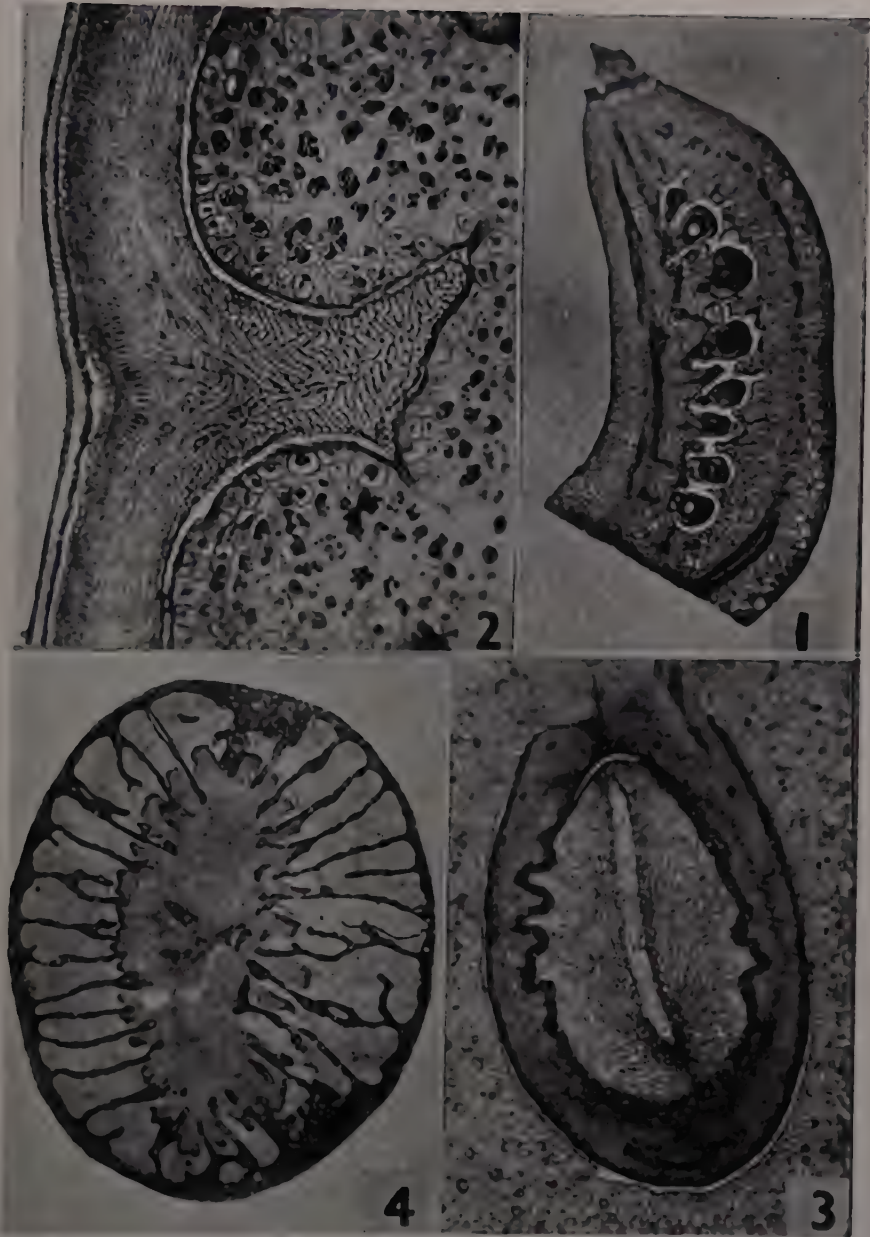
EXPLANATION OF PLATE VI

FIGS. 1 and 2. *Cananga odorata*.

- FIG. 1. L.s. of carpel along the dorsiventral plane showing ingrowth of the carpellary tissue, $\times 26$.
- FIG. 2. Part of a section of mature seed showing seedcoat, rumination ingrowth and endosperm, $\times 100$.

FIGS. 3 and 4. *Milusa wightiana*

- FIG. 3. L.s. of young seed showing uniseriate endosperm and initiation of rumination, $\times 40$.
- FIG. 4. L.s. of seed showing nucellus, rumination and endosperm. Note growth of endosperm in the form of lobes, $\times 12$.



K. Periasamy and B. G. L. Swamy

FIGS. 1-4

INHERITANCE OF SOME MORPHOLOGICAL CHARACTERS IN INTERVARIETAL CROSSES OF *TRITICUM AESTIVUM* L.

BY S. M. SIKKA, K. B. L. JAIN AND K. S. PARMAR

Division of Botany, Indian Agricultural Research Institute, New Delhi

(Received for publication on December 10, 1959)

IN wheat breeding work, the local tastes of the wheat growers have to be fully kept in view. In the major wheat-growing areas in India, the fully awned types are preferred over the awnless or tip awned types because the former are considered to be less liable to bird and animal damage than the latter ones. It is only in certain parts of the hills, where the duration between the harvesting of wheat crop and the onset of the monsoon is rather short that the cultivators prefer awnless, easily thrashable wheats. Similarly amber-coloured, hard, lustrous grains are preferred to the red ones in major parts of the country.

A number of wheat varieties both exotic and Indian are now being used as donors of rust-resistance in the breeding programme at the Botany Division, Indian Agricultural Research Institute. Most of these varieties are either awnless (or tipped) or have soft, dull, red grains. A knowledge of the mode of inheritance of these characters serves a useful guide in planning breeding programme to obtain commercially acceptable segregates.

The crosses were made by the authors primarily for studying the combining ability of different rust-resistant wheat varieties, but these were also used for finding out the mode of inheritance of certain qualitative characters, such as, awning, grain colour, lustrousness of grains, glume colour, awn colour, glume pubescence and auricle hairiness. These data were also analysed to determine if any association existed between these different characters. The present paper embodies the results obtained in this study over a period of two years, 1956-57 and 1957-58.

MATERIALS AND METHODS

Ten intervarietal crosses of wheat (*T. aestivum* L.), viz., N.P. 718 × E. 220, N.P. 718 × E. 572, N.P. 718 × E. 871, N.P. 718 × E. 952, N.P. 718 × E. 1844, N.P. 718 × E. 1913, N.P. 718 × E. 1951, N.P. 718 × N.P. 723, N.P. 718 × N.P. 790 and N.P. 718 × C. 591, were studied with regard to the following characters:

1. Awning,
2. Grain colour,

3. Lustrousness of grains,
4. Glume colour,
5. Awn colour,
6. Glume pubescence,
7. Auricle hairiness.

The F_1 and F_2 generations of these crosses were studied during the two-year period, 1956-57 and 1957-58, while in 1957-58, the F_3 generation was also taken up for the study. The different characters of the parents involved in the crosses are set out in Table I.

TABLE I
Characteristics of the parents under study

Variety	Auricle hairiness	Glume pubescence	Glume colour	Awning	Awn colour	Grain colour	Grain lustrousness
N.P. 718	.. Hairy	Glabrous	White	Fully-awned	White	White	Lustrous
E. 220 (Kenya C. 10854)	..	..	Brown	Long-tipped	Brown	..	Dull
E. 572 (Ridley)	..	..	White	..	White	..	..
E. 871 (Timestein derivative 1495-A, 1-31-2-1)	Glabrous	..	..	Fully awned	..	..	..
E. 952 (Rionegro)	.. Hairy	..	..	..	..	Red	..
E. 1844 (Supremo \times Mentana)	..	..	Brown	..	Brown	..	..
E. 1913 (Kenya Gular—Pilot \times K. 58—New Thatch)	..	..	White	..	White	..	..
E. 1951 (Kenya 338 AC : 2E.2.1.49 : 89)	Glabrous	..	..	Long-tipped	..	White	..
N.P. 723	.. Hairy	..	Brown	Fully-awned	Brown	..	Lustrous
N.P. 790	..	..	..	Awnless	..	Red	Dull
Pb.C. 591	..	Pubescent	White	Fully-awned	Black	White	Lustrous

E. = Refers to the accession number given to exotic wheats at the Indian Agricultural Research Institute.

N.P. (New Pusa) = Refers to improved strains produced at the same Institute.

For recording awning, five classes, as suggested by Pal *et al.* (1941), were taken. In analysing the data, however, only fully awned class was kept separate and the remaining four classes were grouped together.

For grain colour, two classes, viz., red and white, were taken into consideration.

As regards grain lustrousness, three classes, viz., dull, semi-lustrous and lustrous, were taken. For the purpose of genetical interpretation, however, two classes, dull and semi-lustrous, were combined together and compared against the lustrous group.

The different grades suggested by Pal *et al.* (1941) for glume colour were taken into account while studying the mode of inheritance of this character. Grades G₁ and G₂ indicated white colour, while G₃ and G₄ indicated different shades of brown.

In recording awn colour, differentiation was made into three classes, viz., black, brown and white. The observations with regard to this character were recorded at two stages, i.e., at the time of maturity and after maturity of the crop.

Three different classes, viz., glabrous, sparsely hairy and densely hairy, were considered for glume and auricle hairiness. The latter two classes, however, were not quite distinct. For auricle hairiness, the observations were recorded at the seedlings stage (about 2½ months

TABLE II

Mode of inheritance of awning in the F₂ and F₃ generations

Year	Generation	Observed No. of F ₂ plants/F ₃ families				Expected ratio	Deviation	X ²	P. value
		Awnletted	Segregating	Fully-awned	Total				
(i) Cross N.P. 718 × E. 220									
1956-57	F ₂	148	..	38	186	(3 : 1)	± 8.5	2.071	.20-.10
1957-58	F ₂	244	..	80	324	(3 : 1)	± 1.0	0.016	.90-.80
1957-58	F ₃	2	11	7	20	(1 : 2 : 1)	..	2.7	.30-.20
(ii) Cross N.P. 718 × E. 572									
1956-57	F ₂	108	..	38	146	(3 : 1)	± 2.5	0.082	.80-.70
1957-58	F ₂	210	..	70	280	(3 : 1)	± 0.0	0.000	1.00
1957-58	F ₃	3	7	10	20	(1 : 2 : 1)	..	6.7	.05-.02
(iii) Cross N.P. 718 × E. 1951									
1956-57	F ₂	119	..	35	154	(3 : 1)	± 3.5	0.429	.70-.50
1957-58	F ₂	203	..	53	256	(3 : 1)	± 11.0	2.52	.20-.10
1957-58	F ₃	2	12	6	20	(1 : 2 : 1)	..	1.4	.504-.0

after sowing), while for glume pubescence observations were recorded at the time of harvest.

EXPERIMENTAL RESULTS

1. Inheritance of Awning

The mode of inheritance of awning was studied in the three crosses of N.P. 718 (fully-awned) with E. 220, E. 572 and E. 1951, the long-tipped varieties. The F_1 plants in all the crosses were long-tipped. The data regarding segregation in F_2 and F_3 generations are given in Table II.

The F_2 and F_3 segregations in all the three crosses, *viz.*, N.P. \times 718 E. 220, N.P. 718 \times E. 572 and N.P. 718 \times E. 1951, showed that this character was controlled on a monohybrid ratio of 3 awnletted: 1 fully-awned.

2. Inheritance of Grain Colour

The mode of inheritance of grain colour was studied in three crosses of N.P. 718 (white-grained) with red-grained varieties, E. 952, E. 1844 and E. 1913. In the F_1 , red colour of the grains was dominant over white colour of the grains in all the three crosses. The segregations observed in F_2 and F_3 generations are summarized in Table III.

TABLE III

Mode of inheritance of grain colour in the F_2 and F_3 generations

Year	Generation	Observed number of F ₂ plants/ F ₃ families					Expected ratio	Deviation	X ²	P. value
		Red	Segregating		White	Total				
			15 : 1	3 : 1						
(i) Cross N.P. 718 × E. 952										
1956-57	F ₂	161	..	..	45	206	(3 : 1)	± 6.5	1.093	.30-.20
1957-58	F ₂	219	..	..	65	284	(3 : 1)	± 6.0	0.676	.50-.40
1957-58	F ₃	3	..	10	7	20	(1 : 2 : 1)	..	1.6	.50-.40
(ii) Cross N.P. 718 × E. 1844										
1956-57	F ₂	184	..	..	64	248	(3 : 1)	± 2.0	0.086	.80-.70
1957-58	F ₂	195	..	..	57	252	(3 : 1)	± 6.0	0.760	.40-.30
1957-58	F ₃	4	..	12	4	20	(1 : 2 : 1)	..	0.8	.70-.50
(iii) Cross N.P. 718 × E. 1913										
1956-57	F ₂	189	..	..	14	203	(15 : 1)	± 1.32	0.023	.90-.80
1957-58	F ₂	194	..	..	16	210	(15 : 1)	± 2.9	0.685	.50-.40
1957-58	F ₃	7	6	7	..	20	(7 : 4 : 4 : 1)	..	2.60	.30-.20

In the crosses, N.P. 718 \times E. 952 and N.P. 718 \times E. 1844 the segregations in the F_2 and F_3 showed a good fit to a simple monohybrid ratio (3 red: 1 white). In the cross N.P. 718 \times E. 1913, the F_2 and F_3 segregations showed the operation of two duplicate dominant factors for red grain colour.

3. Inheritance of Grain Lustrousness

Four crosses, viz., N.P. 718 \times E. 871, N.P. 718 \times E. 1913, N.P. 718 \times E. 1951 and N.P. 718 \times N.P. 790 were studied with regard to the mode of inheritance of grain lustrousness. N.P. 718 had lustrous grains, while E. 871, E. 1913, E. 1951 and N.P. 790 had dull grains. The F_1 in all the crosses had dull grains, showing its dominance over lustrousness. The details of the segregations in the F_2 and F_3 generations are summarized in Table IV.

The F_2 segregations showed a good fit to a ratio of 3 dull: 1 lustrous grains in all the crosses. The segregation between the F_3 families was in the ratio of 1 homozygous dull: 2 segregating: 1 homozygous lustrous, indicating that this character is inherited on a simple monohybrid ratio.

TABLE IV

Mode of inheritance of grain lustrousness in the F_2 and F_3 generations

Year	Generation	Observed number of F_2 plants/ F_3 families				Expected ratio	Deviation	X^2	P. value
		Dull	Segregating (3:1)	Lustrous	Total				
1957-58	(i) Cross N.P. 718 \times E. 871								
	F_2	159	..	63	222	(3:1)	± 7.5	3.73	.10-.05
	F_3	3	12	5	20	(1:2:1)	..	0.6	.70-.50
"	(ii) Cross N.P. 718 \times E. 1913								
	F_2	169	..	41	210	(3:1)	± 11.5	3.27	.10-.05
	F_3	4	14	2	20	(1:2:1)	..	3.6	.20-.10
"	(iii) Cross N.P. 718 \times E. 1951								
	F_2	191	..	61	252	(3:1)	± 2.0	0.08	.80-.70
	F_3	2	10	8	20	(1:2:1)	..	3.6	.20-.10
"	(iv) Cross N.P. 718 \times N.P. 790								
	F_2	219	..	69	288	(3:1)	± 3.0	0.17	.70-.60
	F_3	6	10	4	20	(1:2:1)	..	0.4	.90-.85

4. Inheritance of Glume Colour

Three crosses of N.P. 718 (white glumes) with brown-glumed varieties, E. 220, E. 1844 and N.P. 723 were studied. The F_1 showed dominance of brown glumes over the white glumes. The segregations observed in the F_2 and F_3 generations are set out in Table V.

TABLE V

Mode of inheritance of glume colour in F_2 and F_3 generations

Year	Generation	Observed number of F ₂ plants/F ₃ families				Expected ratio	Deviation	X ²	P. value
		Brown	Segregating	White	Total				
(i) Cross N.P. 718 × E. 220									
1956-57	F ₂	135	..	51	186	(3 : 1)	± 4.5	0.581	.50-.30
1957-58	F ₂	198	..	70	268	(3 : 1)	± 3.0	0.179	.85-.80
1957-58	F ₃	4	12	4	20	(1 : 2 : 1)	..	0.6	.85-.80
(ii) Cross N.P. 718 × E. 1844									
1956-57	F ₂	181	..	67	248	(3 : 1)	± 5.0	0.537	.50-.30
1957-58	F ₂	184	..	75	259	(3 : 1)	± 10.25	2.053	.20-.10
1957-58	F ₃	4	11	5	20	(1 : 2 : 1)	..	0.3	.90-.80
(iii) Cross N.P. 718 × N.P. 723									
1956-57	F ₂	111	..	54	165	(3 : 1)	± 12.75	5.254	.05-.02
1957-58	F ₂	181	..	61	242	(3 : 1)	± 0.5	0.005	.99-.95
1957-58	F ₃	3	14	3	20	(1 : 2 : 1)	..	3.2	.30-.20

In the F_2 and F_3 , a large range of variation in the intensity of brown colour of glumes was obtained. When all the plants showing brown colour were grouped together and compared against white-glumed plants, the F_2 data showed a good fit to a ratio of 3 brown: 1 white. These observations were further confirmed by the F_3 data.

5. Inheritance of Awn Colour

(a) *Brown vs. white awns.*—The mode of inheritance of brown awn colour was studied in three crosses, *viz.*, N.P. 718 (W) \times E. 220 (Br), N.P. 718 \times E. 1844 (Br) and N.P. 718 \times N.P. 723 (Br). The F_1 showed dominance of brown awns over white awns. The segregations obtained in the F_2 and F_3 are given in Table VI.

INTERVARIETAL CROSSES OF TRITICUM AESTIVUM 223

TABLE VI

Mode of inheritance of brown awn colour in the F₂ and F₃ generations

Generation	Observed number of F ₂ plants/ F ₃ families				Expected ratio	Deviation	X ²	P. value
	Brown	Segre- gating	White	Total				
	(i) Cross N.P. 718 × E. 220							
F ₂	198	..	70	268	(3 : 1)	± 3.0	1.179	.85-.80
F ₃	4	12	4	20	(1 : 2 : 1)	..	0.6	.85-.80
	(ii) Cross N.P. 718 × E. 1844							
F ₂	184	..	75	259	(3 : 1)	±10.25	2.053	.20-.10
F ₃	4	11	5	20	(1 : 2 : 1)	..	0.3	.90-.80
	(iii) Cross N.P. 718 × N.P. 723							
F ₂	181	..	61	242	(3 : 1)	± 0.5	0.005	.99-.95
F ₃	5	10	5	20	(1 : 2 : 1)	..	3.2	.30-.20

The F₂ segregated into a ratio of 3 brown: 1 white glumes in the different crosses under study. The segregation in the F₃ supplemented the F₂ findings.

(b) *Black vs. white awns*.—The inheritance of black awn colour was studied in only one cross, viz., N.P. 718 (W) × C. 591 (Bl). The F₂ and F₃ data are set out in Table VII.

TABLE VII

Mode of inheritance of black awn colour in the F₂ and F₃ generations of the cross N.P. 718 × C. 591

Generation	Number of F ₂ plants/F ₃ families				X ²	P. value
	Black	Segregating	White	Total		
F ₂ observed ..	204	..	68	272	..	..
Expected (3 : 1)	204	..	68	..	0.00	1.00
F ₃ observed ..	7	9	4	20	..	..
Expected (1 : 2 : 1)	5	10	5	..	1.1	.70-.50

The black awns of C. 591 showed dominance over the white awns of N.P. 718 in the F_1 . The segregations observed in the F_2 and F_3 showed that the expression of this character was controlled by a single factor pair.

6. Inheritance of Glume Pubescence

The inheritance of glume pubescence was studied in the cross N.P. 718 (glabrous) \times C. 591 (pubescent). The data of F_2 and F_3 segregations are set out in Table VIII.

TABLE VIII

Mode of inheritance of glume pubescence in the F_2 and F_3 generations of the cross N.P. 718 \times C. 591

Year	Generation	Number of F_2 plants/ F_3 families				X^2	P. value
		Pubescent	Segregating	Glabrous	Total		
1956-57	F_2 observed ..	138	..	49	187	..	..
	Expected (3 : 1)	140.25	..	46.75	..	1.118	.30-.20
1957-58	F_2 observed ..	206	..	66	272	..	..
	Expected (3 : 1)	204	..	68	..	0.078	.90-.80
1957-58	F_3 observed ..	5	11	4	20	..	..
	Expected (1 : 2 : 1)	5	10	5	..	0.3	.90-.80

Unlike C. 591, the F_1 plants were sparsely pubescent. In the F_2 , thickly pubescent, sparsely pubescent and glabrous types of plants were observed. However, it was not possible to classify the densely pubescent and sparsely pubescent plants separately into different groups. Therefore only two classes, viz., pubescent and glabrous were taken into consideration for genetical interpretation. The F_2 segregation showed a good fit to a ratio of 3 pubescent : 1 glabrous. The segregation in the F_3 confirmed that this character was controlled by a single gene pair.

7. Inheritance of Auricle Hairiness

Two crosses, viz., N.P. 718 \times E. 871 and N.P. 718 \times E. 1951 were studied with regard to auricle hairiness. N.P. 718 has densely hairy auricles, while E. 871 and E. 1951 have glabrous auricles. The F_2 and F_3 segregations are summarized in Table IX.

TABLE IX

Year	Generation	Observed number of F ₂ plants/ F ₃ families				Expected ratio	Devia- tion	X ²	P. value
		Hairy	Segre- gating	Glabrous	Total				
	(i)	Cross N.P. 718 × E. 871							
1956-57	F ₂	138	..	41	179	(3 : 1)	± 3.75	0.419	.70-.50
1957-58	F ₂	194	..	52	246	(3 : 1)	± 9.5	1.95	.20-.10
1957-58	F ₃	6	9	5	20	(1 : 2 : 1)	..	0.3	.90-.80
	(ii)	Cross N.P. 718 × E. 1951							
1957-58	F ₂	205	..	62	267	(3 : 1)	± 4.75	0.37	.70-.60
1957-58	F ₃	8	9	3	20	(1 : 2 : 1)	..	2.7	.30-.20

The F₁ in both the crosses was sparsely hairy, showing the partial dominance of this character. In the F₂ and F₃ generations, thickly hairy, sparsely hairy and glabrous plants were observed. As the classification of the densely and sparsely hairy types into different groups was found to be difficult, only two classes, hairy and glabrous, were taken into consideration. The segregations observed in the F₂ and F₃, revealed that this character was controlled by one factor difference.

8. Association between Different Characters

With a view to determining the linkage relationship, if any, between any two of the characters studied, the F₂ data of the character combinations were analysed by X² test for independence. In all, ten character combinations were studied in different crosses. Table X shows the summary of this analysis.

It would be seen from the data given in Table X that of the ten character combinations reported above, eight were independent in inheritance. The joint segregation for brown glume colour and brown awn colour showed absolute linkage between these characters in all the four crosses under study. The P value of X² for the joint segregation of black awn colour and glume pubescence showed significant departure from independence, indicating thereby, that these characters were linked. The recombination value was, therefore, calculated by the product-ratio method outlined by Immer (1930). The observed and expected (on C.O. value) frequencies of the different phenotypes in the F₂ generation are given in Table XI.

TABLE X
 χ^2 test for independence of characters as indicated by the F_2

Character combination	Cross	Year of study	F_2 population	χ^2	P. value
1 Awnedness in relation to :					
(a) Grain colour ..	N.P. 718 \times N.P. 790	1956-57	160	0.520	.50-.30
	"	1957-58	273	0.0001	1.0-.99
(b) Glume colour ..	N.P. 718 \times N.P. 790	1956-57	150	1.557	.30-.20
	"	1957-58	271	2.079	.20-.10
	N.P. 718 \times E. 220	1956-57	185	0.0005	.99-.98
	"	1957-58	263	2.380	.20-.10
(c) Auricle hairiness .	N.P. 718 \times E. 1951	1957-58	255	0.301	.70-.50
(d) Grain lustrousness ..	N.P. 718 \times N.P. 790	1957-58	267	0.213	.70-.50
	N.P. 718 \times E. 1951	1957-58	249	2.192	.20-.10
2 Grain lustrousness in relation to :					
(a) Grain colour ..	N.P. 718 \times N.P. 790	1957-58	265	0.015	.95-.90
	N.P. 718 \times E. 1913	1957-58	210	0.0004	.99-.98
(b) Auricle hairiness ..	N.P. 718 \times E. 871	1957-58	206	0.046	.90-.80
	N.P. 718 \times E. 1951	1957-58	257	2.240	.20-.10
(c) Glume colour ..	N.P. 718 \times N.P. 790	1957-58	268	0.097	.80-.70
3 Grain colour in relation to :					
Glume colour ..	N.P. 718 \times E. 1844	1956-57	248	1.074	.30
	"	1957-58	253	0.967	.50-.30
	N.P. 718 \times N.P. 790	1956-57	160	0.378	.70-.50
	"	1957-58	267	0.075	.80-.70
4 Black awn colour in relation to :					
Glume pubescence ..	N.P. 718 \times C. 591	1957-58	271	127.199	< .01
5 Brown awn colour in relation to :					
Brown glume colour ..	N.P. 718 \times E. 220	1957-58	263	Absolute linkage	
	N.P. 718 \times E. 1844	1957-58	253	"	"
	N.P. 718 \times N.P. 723	1957-58	271	"	"
	N.P. 718 \times N.P. 790	1957-58	267	"	"

TABLE XI

Phenotypic distribution with percentage recombination for black awn colour and glume pubescence from the F_2 of the cross N.P. 718 \times Pb.C. 591

Material	Number of plants				Total	X ²	P. value
	Pubescent glumes		Glabrous glumes				
	Black awns	White awns	Black awns	White awns			
F ₂ observed ..	191	14	17	49	271	..	..
Expected (12.33±2.16%)	187.57	15.68	15.68	52.07	..	0.535	.95-.90

It will be evident that the genes for black awn colour and glume pubescence were closely linked with a cross over value of 12.33 ± 2.16 per cent.

DISCUSSION

In the crosses involving awnletted \times fully-awned varieties, Howard and Howard (1912), Goulden *et al.* (1928), Waterhouse (1930), Torrie (1936), Watkins and Elerton (1940), Abbasi (1949), Sen and Joshi (1955) and others observed this character to be controlled by a single pair of factors. Pal, Sikka and Rao (1956) studied the cross E. 572 (long-tipped) \times C. 518 (fully-awned) and concluded that long-tipped condition of E. 572 was monogenically dominant over the fully-awned type of C. 518. In the present study the inheritance of awning was studied in three crosses of N.P. 718 (fully-awned) with long-tipped varieties, E. 220, E. 572 and E. 1951. The F_1 in all the crosses was long-tipped. In the crosses N.P. 718 \times E. 572 and N.P. 718 \times E. 1951, the F_2 segregated into a ratio of 3 long-tipped : 1 fully-awned, indicating thereby, that this character was controlled by a simple Mendelian ratio. In the cross N.P. 718 \times E. 220, however, the F_2 segregation for awning was of complex nature. Short-tipped, long-tipped, half-awned and fully-awned types were realized in the proportion of 6.4 per cent., 40.6 per cent., 26.8 per cent. and 26.2 per cent. respectively. However, on classifying the F_2 segregates into two classes, fully-awned and partially awned, as an attempt at genetical interpretation, it was found that these gave a good fit to a ratio of 1 fully-awned : 3 partially awned. Sen and Joshi (1955) also observed the same type of complicated segregation in the cross E. 220 \times C. 591. The proportion of F_2 segregates observed were 10.5 per cent., S.T., 33.3 per cent., L.T., 31.0 per cent., H.B., and 25.2 per cent., F.B. It was assumed that some modifier genes were operating in addition to the major gene. The results obtained in this study are, therefore, in accord with those of Sen and Joshi. Recent studies with wheat monosomics and nullisomics have revealed that awn character

is quite complex and as many as ten chromosomes, viz., II, III, VIII, IX, X, XII, XVI, XVII, XX and XXI are concerned in determining the expression of this character; four of them, viz., VIII, IX, X and XVII carrying factors for awn suppression and the rest of them carrying awn-promoting factors (Sears, 1944; O'Mara, 1948; Heyne and Livers, 1953; Wiggin, 1955; Sikka *et al.*, 1957, 1959 and others). In the crosses of E. 220 with Chinese Spring monosomics, Sikka *et al.* (1959) reported that E. 220 had the recessive alleles of Hd and B₅ in Chromosomes VIII and X respectively and dominant awn inhibitor, B₁, on chromosome IX.

From the data so far available, red grain colour in wheat is reported to be controlled by three pairs of 'R' genes which are additive, dominant or partial dominant and are inherited independently (Biffen, 1905; Nilsson-Ehle, 1911; Howard and Howard, 1912; Gaines, 1917; Heyne and Johnston, 1954; Sikka and Rao, 1957; Ghosh, Sikka and Rao, 1958 and others). Depending upon the number of genes by which red-grained and white-grained parents differ from each other, a monohybrid (3:1), dihybrid (15:1) or trihybrid (63:1) ratios are obtained. In the present study the mode of inheritance of grain colour was studied in three crosses of N.P. 718, an amber-grained variety, with E. 952, E. 1913 and E. 1844, the red-grained varieties. The data revealed that E. 952 and E. 1844 carried a single pair of dominant genes for red grain colour and E. 1913 carried two dominant gene pairs. Ghosh, Sikka and Rao (1958) reported that N.P. 718 carried three recessive alleles, $r_1 r_1 r_2 r_2 r_3 r_3$ for white grains. It would, therefore, be of interest to find out whether E. 952, E. 1844 and E. 1913 have any common genes in them for grain colour. If the factor carried by E. 952 differs from the one carried by E. 1844, the F₂ of the cross involving these parents will segregate into a ratio of 15 red : 1 white. Similarly when E. 952 and E. 1844 are crossed with E. 1913, which carries two dominant genes for grain colour, we should expect, in the F₂, a segregation ratio of 63 red : 1 white, if the genes for grain colour in these crosses are different from each other.

The inheritance of lustrousness of grains was studied in four crosses of N.P. 718 (lustrous grains) with E. 871, E. 1913, E. 1951 and N.P. 790 (dull and starchy grains). The expression of this character, to some extent, is influenced by environmental factors. The present data, however, showed that dullness was dominant over the lustrousness of grains in all the crosses and inherited in a simple monohybrid ratio. Pal (1944) also reported this character to be controlled by a single factor difference.

Dominance of brown glume colour over white conditioned by one factor difference was reported by a number of workers including Biffen (1905); Stewart and Heywood (1929); Waterhouse (1930); Pal, Sikka and Rao (1955). Unrau (1959), in crosses involving Federation 41 and Chinese Spring monosomics, found the single dominant gene for brown colour of glumes in Federation 41 to be located on Chromosome 1. However, the results obtained by Torrie (1936), Ayad (1952), Sen and Joshi (1955) and Borojevic (1956) indicate the operation of two

dominant complementary genes for red glume colour. In the present study, three crosses involving brown- and white-glumed varieties, viz., N.P. 718 \times E. 220, N.P. 718 \times E. 1844 and N.P. 718 \times N.P. 723 were studied with regard to this character. The F_2 and F_3 data revealed that brown glume colour of E. 220, E. 1844 and N.P. 723 was monogenically dominant over white glume colour of N.P. 718. The results further show that there was a large variation in the intensity of brown glume colour in the segregating population. This suggests that some modifier or minor genes control the intensity of this pigmentation. In the crosses of N.P. 790, a brown-glumed variety, with C. 518, C. 591, N.P. 710 and N.P. 718, the white-glumed varieties, Sikka and Rao (1957) reported that N.P. 790 carries one dominant factor for brown colour. Ghosh, Sikka and Rao (1958) also reported the operation of one factor pair for brown glume colour in the crosses Pb.C. 281 \times Cometa klein, N.P. 718 \times Cometa klein and N.P. 790 \times N.P. 775 studied by them. These results, therefore, show that inheritance of brown glume colour is controlled by a single factor pair.

However, Sen and Joshi (1955) studied the cross E. 220 \times C. 591 and reported that E. 220 carries two dominant complementary genes in homozygous condition, while C. 591 has these in homozygous recessive condition. If the results obtained by Sen and Joshi are also accommodated in the results obtained in this study and those reported earlier (Sikka and Rao, 1957), monohybrid segregations in the crosses N.P. 790 \times N.P. 718, N.P. 790 \times C. 591 and N.P. 718 \times E. 220 and dihybrid ratio in the cross E. 220 \times C. 591 can be explained by assuming that three pairs of genes, viz., two dominant complementary genes (*AABB*) and one independent dominant gene (*DD*) control the inheritance of brown glume colour in these varieties. On this assumption, therefore, the genetic constitution of E. 220, N.P. 718 and C. 591 would be *AABB dd*, *AA bb dd* and *aa bb dd* respectively, while N.P. 790, E. 1844 and N.P. 723 would carry the genes *AA bb DD* or *aa bb DD*. It would, therefore, appear that if N.P. 718, which has white glumes, is crossed with the white-glumed varieties with *aa BB dd* genetic constitution, the F_1 will have brown glumes and the F_2 will segregate into a ratio of 9 brown : 7 white. In the present study, eight crosses of N.P. 718 with the white-glumed varieties, E. 572, E. 871, E. 952, E. 957, E. 1913, H.D. (52)-30 and C. 591, were, therefore, studied to find out if any such segregation occurred in these crosses. However, the F_1 in all the crosses was white-glumed and no segregation for brown colour was observed in later generations.

In the light of the data reported above if E. 220, which has been assumed to carry two dominant homozygous complementary genes by Sen and Joshi, is crossed with other brown-glumed varieties such as N.P. 790, E. 1844 and N.P. 723, which carry the independent dominant gene for glume colour, interesting segregations would be obtained in the F_2 generation. For example, we would expect the F_2 of the cross N.P. 790 \times E. 220 to segregate either into a ratio of 15 brown : 1 white, if N.P. 790 is assumed to have the genetic constitution *AA bb DD* or would show a segregating ratio of 57 brown : 7 white, if N.P. 790 carries

aa bb DD genes. The crosses are, therefore, underway to confirm the genotypes of these varieties. In case there is no segregation for white glumes in this cross that would indicate that the assumption that E. 220 carries two dominant genes, as reported by Sen and Joshi, will have to be considered with reservation and the cross E. 220 \times C. 591 originally studied by these authors will have to be repeated with regard to segregation for this character.

In the crosses of white-awned variety N.P. 718 with brown-awned or awnletted varieties, E. 220, E. 1844 and N.P. 723 and black-awned variety Pb.C. 591, brown and black colours were monogenically dominant over the white awns, the F_2 segregations being 3 brown : 1 white and 3 black : 1 white respectively. Similar observations were made by Sigfusson (1932) and Knowles (1943). Ghosh, Sikka and Rao (1958) assumed that white-awned variety carried two pairs of genes in recessive condition.

The inheritance of glume pubescence of Pb.C. 591 appeared to be controlled by a single pair of partially dominant genes, the F_1 being not as pubescent as the parent Pb.C. 591. Glume pubescence controlled by a single factor difference was also reported by Kadam (1936), Sen and Joshi (1955), Pal, Sikka and Rao (1956), Sikka and Rao (1957) and others. Sears (1953) reported that dominant gene for pubescence of glumes in variety Indian was located on Chromosome XIV. Howard and Howard (1912, 1915) reported the pubescence to be conditioned by two independently inherited dominant factors, one producing long hairs and the other relatively short hairs. Vacenko (1934) found at one locus two alleles for different hair lengths, in addition to the allele for absence of hairs. Sikka and Rao (1957) observed that certain segregates were less pubescent than the pubescent parents themselves that have entered the crosses. It was assumed that in addition to the major factor, there may be some minor or modifier genes. The results obtained in this study also confirm these conclusions drawn earlier by Sikka and Rao (1957).

The character auricle hairiness in the crosses of N.P. 718 (densely hairy) with E. 871 and E. 1951 (both non-hairy) appeared to be controlled by a single pair of partially dominant genes, the F_1 being sparsely pubescent. Wu and Ausemus (1953) also reported this character to be controlled by a single factor pair.

The results obtained in the present study further revealed that the character awnedness was inherited independently of grain colour, glume colour, auricle hairiness and grain lustrousness. Likewise, grain lustrousness showed independent inheritance from grain colour, auricle hairiness and glume colour. Grain colour was also independently inherited of glume colour.

The genes for black awn colour and glume pubescence showed linkage with a cross over value of 12.33 ± 2.16 per cent. in the cross N.P. 718 \times Pb.C. 591, under study. Vacenko (1934) also reported

linkage between the genes of glume (and awn) colour and glume pubescence in *durum* wheats with a cross over value of 2.4 per cent.

Four crosses were studied for combined brown glume and brown awn colour inheritance. The brown-glumed parents included in the crosses had brown awns, while white-glumed parents had white awns. In the F_2 and F_3 segregating population, brown-glumed plants were found to have brown awns. Similarly white-glumed plants had white awns. Not even a single plant with recombination characters, *i.e.*, brown glumes with white awns and *vice versa* was observed. This suggests that the same gene or two tightly linked genes controlled the development of brown colour in the glumes and the awns. Kadam (1936) observed that brown glumes and brown awns were inherited together and concluded that the gene *Rg-a* produced both brown glumes and brown awns. Borojevic (1956) also concluded that the genes responsible for red colour of glumes also produced red colour in the awns.

SUMMARY

Ten intervarietal crosses of *Triticum aestivum* L. were studied in F_1 , F_2 and F_3 generations to find out the mode of inheritance and linkages, if any, of characters such as awning, grain colour, grain lustrousness, glume colour, awn colour, glume pubescence and auricle hairiness.

In the crosses of N.P. 718 (fully-awned) with E. 220, E. 572 and E. 1951 (long-tipped), tipped condition was dominant and controlled by one pair of genes.

With regard to grain colour, E. 952 and E. 1844 were found to carry one dominant gene pair, while E. 1913 carries two duplicate factors. The amber colour of N.P. 718 was the bottom recessive.

Dull grains of E. 871, E. 1913, E. 1951 and N.P. 790w were dominant over the lustrous grains of N.P. 718 and inherited on a monohybrid ratio.

Brown glume colour of E. 220, E. 1844 and N.P. 723 was dominant over the white glumes of N.P. 718 and inherited on a simple mendelian ratio. In addition, some minor or modifier genes controlled the intensity of pigmentation.

Black awn colour of Pb.C. 591 and brown awn colours of E. 220, E. 1844 and N.P. 723 were monogenically dominant over the white awns of N.P. 718.

In a cross between densely pubescent (Pb.C. 591) and glabrous glumes (N.P. 718), the F_1 was sparsely pubescent and inherited on a simple monohybrid ratio.

Non-hairy auricles of E. 871 and E. 1951 behaved as a simple recessive to the hairy auricles of N.P. 718 and inherited monofactorially.

The brown colour in the glumes and awns was controlled either by the same gene or two closely linked genes. The black awn colour

showed linkage with glume pubescence with a cross over value of 12.33 ± 2.16 per cent.

ACKNOWLEDGEMENT

We are grateful to Dr. B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi, for his keen interest in the study.

REFERENCES

- ABBASI, F. H. 1949. Inheritance of resistance to stem rust and leaf rust in crosses of Premier and Kenya wheats. *Indian J. Genet.* **9**: 7-17.
- AYAD, M. A. G. 1952. Inheritance studies of some qualitative and quantitative characters in Egyptian varieties of wheat. *Proc. Egypt. Acad. Sci.* **8**: 26-38.
- BIFFEN, R. H. 1905. Mendel's laws of inheritance and wheat breeding. *J. agric. Sci.* **1**: 1-48.
- BOROJEVIC, S. 1956. The occurrence of new colour of glumes and awns in *Triticum vulgare* \times *T. dicoccum*. *Wheat Information Service, Tokyo*, No. 4.
- GAINES, E. F. 1917. Inheritance in wheat, barley and oat hybrids. *Bull. Wash. agric. Exp. Sta.*, No. 135.
- GHOSH, S., SIKKA, S. M. AND RAO, M. V. 1958. Inheritance studies in wheat. IV. Inheritance of rust resistance and other characters. *Indian J. Genet.* **18**: 142-62.
- GOULDEN, C. H., NEATBY, K. W. AND WELSH, J. N. 1928. The inheritance of resistance to *Puccinia graminis tritici* in a cross between two varieties of *Triticum vulgare*. *Phytopathology* **18**: 631-58.
- HARRINGTON, J. B. AND AAMODT, O. S. 1923. Mode of inheritance of resistance to *Puccinia graminis* with relation to seed colour in crosses between varieties of durum wheat. *J. agric. Res.* **24**: 979-96.
- HAYES, H. K. AND ROBERTSON, D. W. 1924. The inheritance of grain colours in wheat. *J. Amer. Soc. Agron.* **16**: 787-90.
- HEYNE, E. J. AND JOHNSTON, C. O. 1954. Inheritance of leaf rust and other characters in crosses among Timstein, Pawnee and Red Chief Wheats. *Agron. J.* **46**: 81-85.
- AND LIVERS, R. W. 1953. Monosomic analysis of leaf rust reaction, awnedness, winter injury and seed colour in Pawnee wheat. *Ibid.* **45**: 54-58.
- HOWARD, A. AND HOWARD, G. L. C. 1912. On the inheritance of some characters in wheat. I. *Mem. Dep. Agric. India (Bot.)* **5**: 1-47.
- — —. 1915. On the inheritance of some characters in wheat. II. *Ibid.* **7**: 273-85.
- IMMER, F. R. 1930. Formulae and tables for calculating linkage intensities. *Genetics* **15**: 81-98.
- KADAM, B. S. 1936. Genetics of Bansi Wheats of Bombay and Deccan and a synthetic khapli. Part I. *Proc. Indian Acad. Sci.* **4B**: 357-69.
- KNOWLES, P. F. 1943. A second factor for awn barbing in durum wheat. *Canad. J. Res.* **21C**: 198-204.
- NILSSON-EHLE, H. 1911. Krenzenysuntersuchungen an Hafer und Weizen. *Acta Univ. Lund, n.f. Avd.* **2**, 7(6): 82.
- O'MARA, J. G. 1948. Awn inheritance in *Triticum vulgare*. *Genetics* **33**: 119.

- PAL, B. P. 1944. Pusa wheats: The wheat breeding work at the Imperial Agricultural Research Institute. *Emp. J. exp. Agric.* **12**: 61-73.
- , and members of sub-committee 1941. The description of crop plant characters and their ranges of variation. III. The variability of Indian wheats. *Indian J. agric. Sci.* **11**: 477-92.
- , SIKKA, S. M. AND RAO, M. V. 1956. Inheritance studies in wheat. *Indian J. Genet.* **16**: 32-46.
- SEARS, E. R. 1944. Cytogenetic studies with polyploid species of wheat. II. Additional chromosome aberrations in *Triticum vulgare*. *Genetics* **29**: 232-46.
- , 1953. Nullisomic analysis in common wheat. *Amer. Nat.* **87**: 245-52.
- SEN, S. AND JOSHI, M. G. 1955. Inheritance of resistance of black rust in wheat. *Indian J. Genet.* **15**: 36-46.
- SIGFUSSON, S. J. 1932. Smooth-awned wheat: Inheritance of barbing and awn colour. *Sci. Agri.* **13**: 185-93.
- SIKKA, S. M. AND RAO, M. V. 1957. Inheritance studies in wheat. II. *Indian J. Genet.* **17**: 7-18.
- , JHA, K. K. AND SWAMINATHAN, M. S. 1959. Monosomic analysis in bread wheat. II. Identification of chromosomes carrying genes for awning and glume beak. *Ibid.* **19**: 56-63.
- , SWAMINATHAN, M. S., SINGH M. P. AND PAL, B. P. 1956. Monosomic analysis of some characters in the wheat variety Cometa Klein (E. 671). *Ibid.* **16**: 24-28.
- STEWART, G. AND HEYWOOD, D. E. 1929. Correlated inheritance in a wheat cross between Federation and a hybrid of Sevier × Dicklow. *J. agric. Res.* **39**: 367-92.
- TORRIE, J. H. 1936. Inheritance studies of several qualitative and quantitative characters in spring wheat crosses between varieties relatively susceptible and resistant to drought. *Canad. J. Res.* **14 C**: 368-85.
- UNRAU, J. 1950. The use of monosomes and nullisomes in cytogenetic studies of common wheat. *Sci. Agric.* **30**: 66-69.
- VACENKO, A. A. 1934. Inheritance of glume pubescence and of black colour of ear in durum wheat. *C.R. Acad. Sci. U.S.S.R.* **4**: 338-43.
- WATERHOUSE, W. L. 1930. Australian rust studies. III. Initial results of breeding for rust resistance. *Proc. Linn. Soc., N. S. W.* **55**: 596-636.
- WATKINS, A. AND ELLERTON, S. 1940. Variation and genetics of the awn in *Triticum*. *J. Genet.* **40**: 243-70.
- WIGGIN, H. C. 1955. Monosomic analysis of stem rust and awn expression in Kenana 52 wheat. *J. Hered.* **46**: 239-46.
- WU, C. S. AND AUSEMUS, E. R. 1953. Inheritance of leaf rust reaction and other characters in a spring wheat cross. *Agron. J.* **45**: 41-48.

CHAROPHYTE NOTES FROM BENARES, U.P., INDIA

BY G. O. ALLEN

St. Oswalds, Eton Green, Godalming, England

(Received for publication on August 25, 1960)

THIS paper concludes a short series of notes, starting from 1925, on charophytes collected in the United Provinces (now Uttar Pradesh) in northern India. They related to the districts of Gonda, Saharanpur, Agra and Bareilly. The present account differs from the others in that none of the plants have been collected by me personally.

Benares (now spelt Banaras) was my first posting on arrival in India in 1908. In charge of my first pony, which hailed from the Maharajah's stables at Ramnagar Fort, was Parsotam who remained in my employ throughout my service. Always ready to assist in my various natural history activities, he was in later years my frequent companion in pond hunting for charophytes.

When I finally left India in 1933, he returned to his village near Benares and except for the war years continued to send me specimens both dried and in fluid till 1951 by which time he had grown too old to ride his bicycle. His collections were practically all made in the Benares district, a few coming from the neighbouring district of Mirzapur.

I had shown Parsotam how to float out specimens and supplied him with a magnifying glass: from time to time I sent him mounting paper and tubes. He managed to mount hundreds of sheets and never sent me anything that was not a charophyte. His main difficulty was evidently in the drying of sheets which especially during the rains is hardly surprising.

The Benares list comprised 16 species of *Nitella* (including one new species) and 13 of *Chara*, a total well above my highest of 23 from Saharanpur.

LIST OF SPECIES

Nitella

1. *N. mirabilis* Gr.
2. *N. acuminata* Br.
3. *N. dispersa* Br.
4. *N. mucronata* Miq.

Chara

1. *C. wallichii* Br.
2. *C. corallina* Willd.
3. *C. braunii* Gmel.
4. *C. gymnopitys* Br.

LIST OF SPECIES (Contd.)

Nitella

5. *N. bengalensis* Kundu
6. *N. patula* Gr. and Allen
7. *N. flagellifera* Gr. and Allen
8. *N. pseudo-flabellata* Br.
9. *N. leptodactyla* Gr.
10. *N. confervacea* Br.
11. *N. oligospira* Br.
12. *N. furcata* Ag.
13. *N. myriotricha* Kütz.
14. *N. saharanpurensis* G. O. Allen
15. *N. hyalina* Ag.
16. *N. stuartii* Br.

Chara

5. *C. erythrogyna* Griffith
6. *C. hydropitys* Reichb.
7. *C. contraria* Kütz.
8. *C. vulgaris* L.
9. *C. aspera* Willd.
10. *C. globularis* Thuill.
11. *C. delicatula* Ag.
12. *C. brachypus* Br.
13. *C. zeylanica* Willd.

*Nitella*1. *N. mirabilis* Groves

This was described in that invaluable paper "Notes on Indian Charophyta" (Groves, 1924) and included a beautiful illustration (pl. 35) by Miss Mary Groves.

Apparently uncommon as I only received it once whereas in Saharanpur, Bareilly and Gonda I found it plentiful.

2. *N. acuminata* Braun

Collected on many occasions, three of the gatherings being of the capitate form.

A great deal has been written about the forms of this species by Braun, T. F. Allen and others and several varieties described. Zaneveld in his "Charophytes of Malaysia and Adjacent Countries" (1940), which includes India, discussed Braun's varieties and reduced them for this area to var. *bélangeri* and var. *subglomerata*, with which he included var. *indica*. He points out that Nordstedt was apparently incorrect in separating var. *subglomerata* from var. *indica* by the oogonia being aggregate in the former and solitary in the latter as on examination of the type of var. *indica* he found them to be geminate. The Benares plants would fall under var. *subglomerata*.

3. *N. dispersa* Braun

Found frequently. As at Saharanpur (Allen, 1928) and Bareilly (Allen, 1936) and Bengal (Agharkar and Kundu, 1937) a number of cases occurred of the ultimate cell of the dactyl being allantoid in shape.

On a single branchlet may be observed every gradation in the ultimate cell from a short conical to an allantoid. The gatherings included, in February 1937, an instance of the capitate form of the species as found at Saharanpur (Allen, 1928. pl. 2).

4. *N. mucronata* Miquel

Common. A gathering from Sarnath in November 1936 was heteromorphous in form.

5. *N. bengalensis* Kundu

I have not seen a specimen of the original gathering but one of Parsotam's plants appears to me to fall within this species (Kundu, 1941). *N. bengalensis* comes close to *N. mucronata* but differs chiefly in having a central ray at the first fork where one might have expected an antheridium, in the rays at the second fork being usually 3-4 and in the lower cell of the dactyl tapering slightly towards the apex.

6. *N. patula* Groves and Allen

N. patula, first described from a Saharanpur specimen, bears some resemblance to *N. mucronata*, but is a larger plant and resembles *N. furcata* in habit, the branchlet rays being markedly divergent. It is three and often four times forked. The dactyl is 2-celled though occasionally at the fourth fork there may be a short narrow 1-celled dactyl.

The oospore membrane was originally described as "subtiliter et regulariter granulata", i.e., finely and evenly granulate, but this should be amended by substituting "reticulata" for "granulata". In the first material I sent Groves in fluid though oogonia were plentiful he only happened to find one ripe oospore. He found it difficult to decide whether the membrane markings were raised or depressed, i.e., granulate or reticulate. Examining some membranes of this species in 1927 I came to the conclusion it was really reticulate and Groves then agreed. The mesh is very fine being 14-16 to the fossula.

Though not mentioned in the original description, there is produced a subsidiary shoot at the first fork to a considerable extent though I do not find this occurs in all specimens even of the same gathering. My attention was drawn to this extra shoot by Dr. Imahori of Japan.

The type was collected on 12 October 1926 being of the same gathering as distributed as No. 6 in *Charophyta Indica* fasc. 1. It is preserved in the British Museum.

Found on a number of occasions by Parsotam.

7. *N. flagellifera* Groves and Allen

This species was described from specimens I gathered at Saharanpur on 28 November 1926 and is No. 5 in my *Charophyta Indica* fasc. 1 a set of which is at Calcutta.

The specimen chosen to illustrate the species (Allen, 1928, pl. 4) shows very clearly its typical habit of growing in broadly spreading tufts with the outline forming half an ellipse and has the additional value of the name being entered in Groves's own hand.

The production of an extra little shoot frequently at the first and also often at the second branchlet node on the central ray is a striking feature of this species. I might explain that this is responsible for the plant's specific name, a less usual meaning of *flagellum* being a young branch.

In the notes to the original description it is stated that the branchlets are often much elongated ($\rightarrow 8$ cm.). I think this should be 4 cm., the total spread of the whorl being c. 8 cm.

The upper cells of the dactyls in both *N. patula* and this species are narrow-conical acute but in *N. flagellifera* the lower cell is considerably broader than in *N. patula*. The oospore membrane is reticulate though somewhat irregular, the meshes being c. 7-8 to the fossula.

Groves considered this species and *N. patula* allied to *N. oligospira* though the relationship does not appear to me a very close one.

N. flagellifera is included in Japanese Charophyta (Imahori, 1954) but the plant depicted in the plate bears no resemblance to the Indian one and differs also in the paucity of the extra shoots and the fine mesh of the membrane decoration.

Collected by Parsotam on numerous occasions.

8. *N. pseudo-flabellata* Braun

Only one very small specimen of this species was collected in February 1938. It agrees quite closely with M. O. P. Iyengar's specimens from Madras that Groves determined as a form of this species.

This being a case where the selection of a type appeared of practical value as Braun's species was based on several rather different forms from five localities I designated Wilford's plant from China at Kew as the type (Allen, 1953).

The main features of this species are 6-8 branchlets, 2-3 or even 4 times forked, the primary ray over half the total length of the branchlet, secondaries usually 6 (-7), tertiaries 4-5 and dactyls 3-4 which are equal and longer than the penultimate rays. Oogonia solitary, oospore 300-350 μ long, 200-240 μ broad, membrane granulate, ridges 6-7; antheridium 200-260 μ in diameter.

9. *N. leptodactyla* Groves

Resembles *N. pseudo-flabellata* in being much forked and in producing many rays but *N. leptodactyla* for one thing is much the more slender of the two, the diameter of the stem being c. 275 μ and of the dactyl only c. 50 μ .

First described from Ceylon (Groves, 1922) with an excellent plate. Gathered on two occasions in Benares.

10. *N. confervacea* Braun (= *N. batrachosperma* Braun)

This minute species was only found once.

11. *N. oligospira* Braun

There are only a few records for India including two from Bengal. I personally did not find any plant belonging to this species. Parsotam made five gatherings that I should refer here.

It is not always an easy species to distinguish from *N. mucronata*. The oogonia of *N. oligospira* are always solitary and not produced at the final fork whereas in *N. mucronata* they are often geminate and often occur at the final fork; the dactyl too in *N. mucronata* is never short.

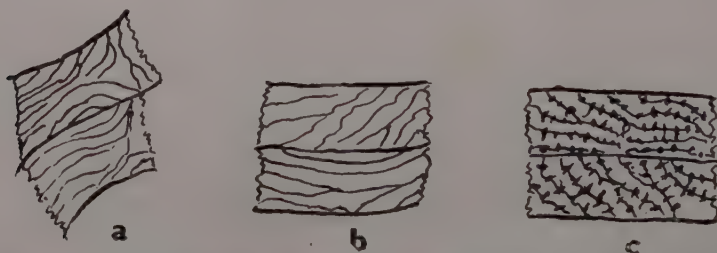
12. *N. furcata* Agardh

Collected on four occasions in Benares.

13. *N. myriotricha* Kützing

One gathering of the female plant only, made by Parsotam in 1937, I refer to *N. myriotricha*. It is covered in mucus, this being apparent on the stem and branchlets as well as round the fruiting heads. The branchlets are thrice forked and the dactyls 3-celled, the lowest cell being the longest and the ultimate the shortest. The oospore, judging from the only two ripe ones I found, is unusually small being only c. 180 μ long; the membrane decoration is a coarse reticulation.

N. Grovesii Kundu (Kundu, 1937) resembles *N. myriotricha* in many respects but is only once or twice forked with considerably less rays at the forks.



TEXT-FIG. 1. *N. saharanpurensis*. Oospore membrane. a. From Saharanpur. b and c. From Benares.

14. *N. saharanpurensis* sp. nov. (Plate VII, Figs. 1, 2 and Text-Fig. 1)

Homoeoclema, arthrodactyla, pluricellulata, conoteles, gloeocephala, monoica. Valde laxa. Ramuli verticillorum 6; partim bis-, plerumque ter-, partim quater-furcati; radii secundarii 8-9, tertiarium 3-7, quaternarii

2-4, quinari 2-4, inaequales. Dactyli plerumque longissimi, ter- (raro quater-) cellulati, cellula ultima conica acuta. Gametangia ad omnes nodos, praeter aliquando ad primum, posita. Oogonia solitaria. Oospores c. 250μ longae; membrana irregulariter striata.

Typus, Hb. G. O. Allen No. 155, prope Saharanpur, U.P., India, lectus, leg. G. O. Allen 12-10-1926, in Herb. Mus. Brit. depositus.

Paratypi, Banaras, U.P., India, ann. 1934 et 1935, leg. Parsotam.

Monoecious. Stem slender, diameter c. 400μ . Internodes long, about twice the length of the branchlets, up to 9 cm. long. Branchlets 6, 2-4 (usually 3) times forked, up to 4 cm. long; primary ray exceeding half the length of the entire branchlet, secondary rays 8-9, tertiary 3-7 some of which are simple and very short whilst others divide into 2-4 (rarely 5) quaternaries, some dividing into 2-4 quinari, all rays unequal. Dactyls usually very long, 3- (rarely 4-) celled, lowest cell much the longest, penultimate considerably longer than the apical cell which though long-conical is quite short.

Gametangia produced together at all nodes, sometimes not at the first. Oogonia solitary. Oospore pale brown, c. 250μ long, 235μ broad, showing 6 well-marked but not high ridges; membrane with long more or less parallel ridges that sometimes take a transverse, sometimes an oblique direction in relation to the spiral ridges (Text-Fig. 1 a). antheridium c. 190μ in diameter.

A very lax plant 25-30 cm. high, conspicuously mucous on the stem and primary rays.

This species was first diagnosed by the late Mr. James Groves on the basis of a gathering I made at Saharanpur on 12 October 1926 (Hb. G.O.A. 155). He noted as the outstanding features the extremely long slender dactyls and the remarkable membrane decoration. He hesitated about publishing a description as he did not know whether the decoration was constant. On the original material that I sent him Groves only found two fairly ripe oospores. The membrane of the first proved so unusual that he broke the second and found it exactly the same and unlike any other oospore membrane he had ever seen.

Parsotam found this species on three occasions in 1934 and 1935. Fortunately the material included some ripe oospores. It was interesting to find that whereas some membranes (Text-Fig. 1 b) exactly resembled those from Saharanpur, others (Text-Fig. 1 c) showed a number of little lateral projections or crossbars on these ridges, the bars occasionally meeting on the two sides and so presenting the appearance of a very early stage towards a reticulate pattern. A somewhat similar "reticulate-striate" membrane decoration did in fact occur in two of T. B. Blow's Madagascar plants (Groves, 1928, pl. 7, Fig. 7). *N. grovesii* differs from the present species in bearing fruit in heads, in the branchlets being only once or twice forked and in the internodes being shorter than the branchlets,

When studying here in 1938 Dr. Kundu kindly compared the material of *N. saharanpurensis* from the two districts. His notes and some oospore membrane photographs he took were very useful to me.

The photograph of *N. saharanpurensis* is reproduced by kind permission of the British Museum (Natural History). The type is being preserved there.

15. *N. hyalina* Agardh

Common. Also found by N. K. Tiwary in December 1925.

16. *N. stuartii* Braun

Only gathered on one occasion. The only other Indian record is from Bareilly in February 1933 (Allen, 1934 and Tex-Fig. 1).

Chara

1. *C. wallichii* Braun

Common.

2. *C. corallina* Willdenow

Common. Found also by N. K. Tiwary.

3. *C. braunii* Gmelin

Fairly common.

4. *C. gymnopitys* Braun (= *C. fibrosa* Ag. fide Zaneveld, 1940, 153)

Only found on two occasions, in 1933 and 1936.

5. *C. erythrogyna* Griffith

Common.

6. *C. hydropitys* Reichenbach

Only found once in 1935.

7. *C. contraria* Kützing

Fairly common. One gathering with amber-coloured oospores and a rather irregular cortex comes near this species but needs collecting further.

8. *C. vulgaris* L

Only one record by Parsotam. Also found by N. K. Tiwary.

9. *C. aspera* Willdenow var. *subinermis* Kützing

The male plant only was found on one occasion in 1933. I did not at first realize what it was. Dr. Filarszky, to whom I happened

to show a mounted slide of this, proceeded to publish his determination as *C. connivens* Br. (Filarszky, 1936). With this I entirely disagree. For one thing there is not a sign of the branchlets being incurved. Zaneveld who of course had not seen the plant repeated this error (Zaneveld, 1940).

The Benares plant differs considerably from that figured from Dholpur (Allen, 1933), the stipulodes being quite small though developed and the spine-cells not much more than papillae.

10. *C. globularis* Thuillier var. *capillaces* (Thuill.) Zaneveld (= *C. fragilis* Desvaux)

Found on a few occasions only, including one by N. K. Tiwary.

11. *C. delicatula* Agardh

Originally sent me by N. K. Tiwary in 1925. Parsotam made one gathering in March 1936.

12. *C. brachypus* Braun

The only record I have of this is a specimen sent by N. K. Tiwary in 1925.

13. *C. zeylanica* Willdenow

N. K. Tiwary sent me this. Also found on a few occasions by Parsotam.

SUMMARY

Lists sixteen species of *Nitella*, including one sp. nov., *N. saharan-purensis*, and thirteen of *Chara*, mainly collected by Parsotam, an ex-employee of the writer, between 1933 and 1951.

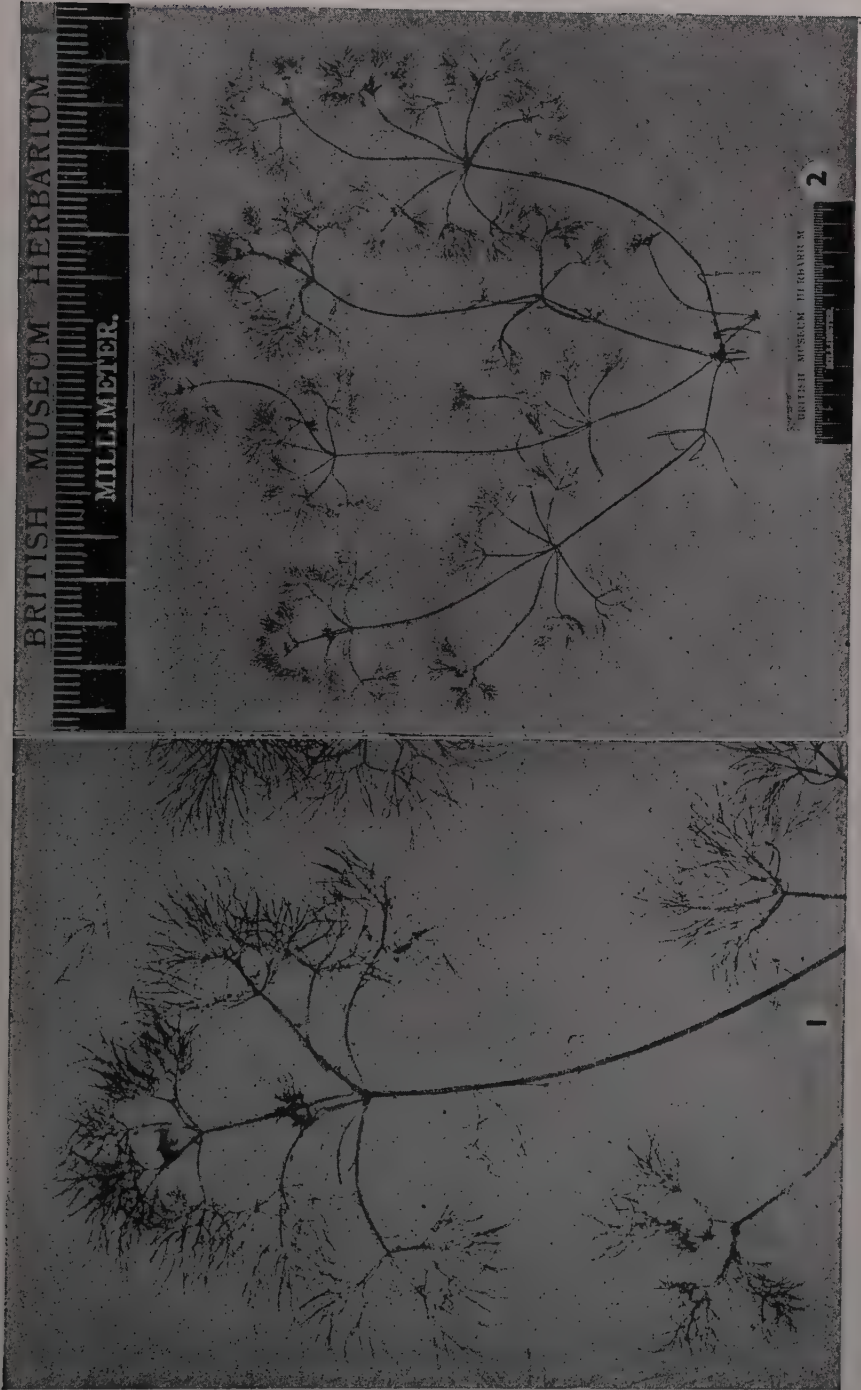
REFERENCES

- AGHARKAR, S. P. AND KUNDU, B. C. 1937. Charophyta of Bengal. *J. Dep. Sci. Calcutta Univ.* **1** (1): 1-24.
- ALLEN, G. O. 1925. Notes on Charophytes from Gonda, U.P. *J. Bombay nat. Hist. Soc.* **30** (3): 589-99.
- . 1928. Charophyte notes from Saharanpur, U.P. *J. Indian bot. Soc.* **7** (2): 49-69.
- . 1933. Charophyte notes from Agra, U.P. *Ibid.* **12** (1): 17-19.
- . 1936. Charophyte notes from Bareilly. *Ibid.* **15** (1): 51-54.
- . 1953. Typification of *Nitella pseudofiabellata* A. Braun. *Ann. Mag. nat. Hist.* **12** (6): 606-08.
- FILARSZY, F. 1936. Idegenföldi Charafélék határozása (Determinatio Characearum Exoticarum). *Mag. Tud. Akad. Matem. és Termész. Értes.* **55**: 476-97, pls. 1-8.
- GROVES, J. 1922. On Charophyta collected by Mr. Thomas Bates Blow, F.L.S., in Ceylon. *J. Linn. Soc. (Bot.)* **46**: 97-103, pl. 6.
- . 1924. Notes on Indian Charophyta. *Ibid.* **46**: 359-76, pls. 35-36.

- GROVES, J. 1928. On Charophyta collected by Mr. Thomas Bates Blow, F.L.S., in Madagascar. *J. Linn. Soc. (Bot.)* **48**: 125-37, pls. 4-7.
- AND ALLEN, G. O. 1927. On some Indian Charophyta. *J. Bot. Lond.* **65**: 335-39.
- IMAFORI, K. 1954. *Japanese Charophyta*. Kanazawa Univ., Japan.
- KUNDU, S. C. 1937. A new species of polyarthrodactylous *Nitella* with a review of the allied species. *J. Indian bot. Soc.* **16**(5): 263-68, Figs. 1-15.
- . 1941. Two new *Nitellas*. *J. Bombay nat. Hist. Soc.* **42**(4): 843-46, pls. 1-2.
- ZANEVELD, J. S. 1940. The Charophyta of Malaysia and adjacent countries. *Blumea* **4**: 1-224, Figs. 1-21.

EXPLANATION OF PLATE VII

FIGS. 1, 2. *Nitella saharanpurens* sp. nov. Photographs of type specimen. G. O. Allen No. 155, Fig. 1, shows a portion of Fig. 2 enlarged.



FIGS. 1-2

STUDIES ON THE ANATOMICAL VARIABILITY IN THE STEM OF *PHOENIX SYLVESTRIS*

I. Trends in the Behaviour of Certain Cells and Tissues

BY B. G. L. SWAMY AND E. GOVINDARAJALU

Department of Botany, Presidency College, Madras-5

(Received for publication on February 3, 1960)

STUDIES on the range of variability of anatomical structure within the stem and branches of a single plant may be said to have begun with the discovery of the variations in regard to the fibre length in *Pinus sylvestris* by Sanio (1872). Later investigations by Hartig and Webber (1885), Eichorn (1895), Bailey and Shepard (1915), amongst others, revealed new data that established the general soundness of Sanio's 'Laws', at the same time necessitating the addition of certain amendments. As two reviews on the nature and trends of variability of tracheary cells have recently appeared (Bisset, 1949; Spurr and Hyvarinen, 1954), a very brief summary of the pertinent conclusions may be given as under:—

(a) In the stem and branches, the imperforate tracheary cells increase rapidly in length from centre outwards until a definite value is reached and then either remain constant or show slight fluctuations or undergo gradual decrease towards the periphery.

(b) A similar but less rapid increase in the length of tracheary cells obtains from bottom to top of stems, the maximum linear value occurring at a definite height and decreasing thereafter.

(c) The ultimate length of tracheids or fibres in the branches is generally of a lower order than in the stem; however, in those branches that arise from specific levels of the stem possessing longer imperforate tracheary cells, the corresponding cells are equally longer; and in the branches that arise from regions of the stem containing shorter tracheary cells, possess cells of more or less corresponding length.

(d) In stems or branches that suffer structural defects, knarled areas, pathological lesions, etc., the normal trends become modified and introduce irregularities in dimensional values.

These generalizations are found to be applicable to many of the arborescent gymnosperms and dicotyledons. There are, however, on record some instances of exceptional cases (see Bisset, 1949), which, as Chalk (1930) has expressed, appear to be due to different methods of sampling adopted by the investigators.

Although interest in the anatomy of arborescent palms was evinced as early as the first decade of the nineteenth century (Moldenhawer, 1812) and contributions have appeared rather sporadically till today, no information is yet available with particular reference to the anatomical variability within a single tree. Prior to 1812, a widely held opinion appears to be that the vascular bundles to the young leaves developed in the interior of the stem and thus were surrounded by the foliar strands of older leaves. The cylindrical form of arborescent forms was thought to be the expression of such a peculiar method of growth. Moldenhawer (1812) claimed to have observed a clear line of demarcation between central and peripheral vascular zones in the stem of *Phoenix dactylifera*, a situation which conveyed to him the existence of a peripheral growth that contributed towards the increase in thickness of the stem.

van Mohl's (1845) studies on the structure of palm stems are largely concerned with the course and behaviour of leaf trace bundles within the stem. He recorded numerous instances where the vascular bundles of younger leaves descended downwards from the periphery to the centre by following a broad convex curvature, subsequent to which they aligned themselves more or less in line with the vertical axis of the stem. This finding disproves the opinion held earlier, that the vasculature of younger leaves originate in the centre of the axis. van Mohl further stated in clear terms that the palm stem was unlike that of dicotyledons because of the absence of zones or structures like bark, cortex, pith and rays in the former group although he visualized certain gross similarities of anatomical organization between the tissues of palm stems on the one hand and those of dicotyledons on the other.

The somewhat rambling account of van Mohl also touches upon the structural variability within a stem in reference to two points: (i) that the prosenchymatous region ('liber') of the fibro-vascular bundles face the centre for some distance in the axial region and change their orientation by 180 degrees thereafter, and (ii) that the general structure, size and relative composition of the bundles fluctuate in different regions of the stem.

Another series of investigations with particular reference to the elucidation of the method of the so-called secondary growth in the Palmae emerged from the publication of Karsten's (1847) treatise. This author was impressed by the fact that in arborescent forms the leaves develop for a relatively prolonged period in the initial stages of ontogeny of the plant, while the stem failed to undergo extension-growth; on the other hand, the stem increased conspicuously in radial diameter, keeping pace, so to say, with the origin of new leaves. This thesis appears to have greatly influenced the extensive studies of Schoute (1912), who presented a comparative anatomical account of a wide variety of palm stems. He strived to show that the increase in the girth of palm stems through the activity of a lateral meristem was an intimate continuation of growth of the terminal meristem of the shoot. It must be noted that although Schoute recognized the activity of a lateral meristem in

the increase in thickness of the palm stem, he distinguished this phenomenon as a *diffused* type of growth in contrast to the method of girth increment in a dicotyledonous stem which is accomplished through the functioning of a vascular cambium.

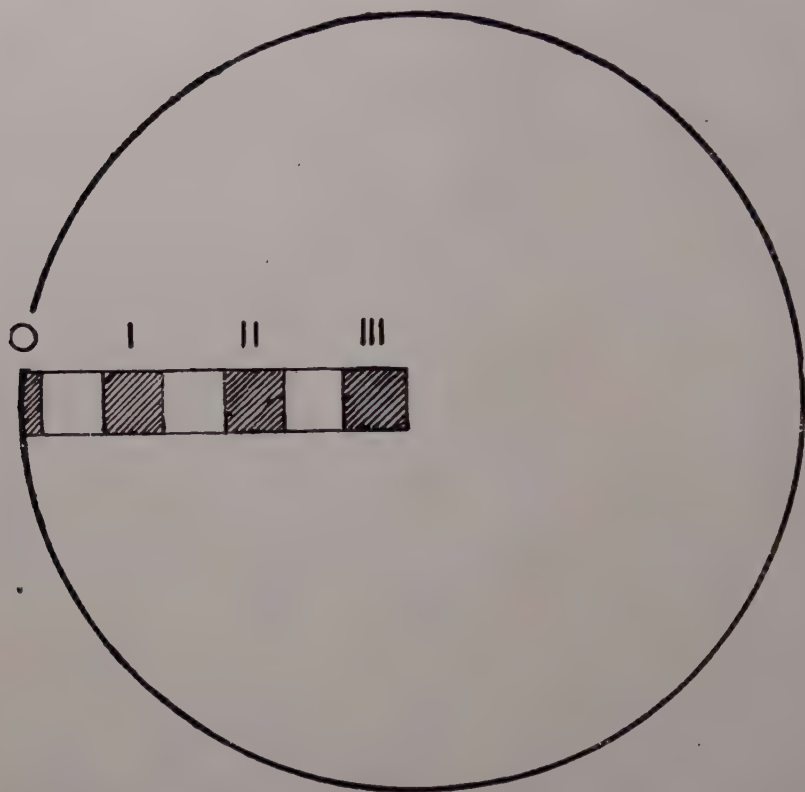
Cheadle's investigations (1937) on the method of secondary thickening of certain woody monocotyledonous stems indicate the activity of a 'thickening ring'. According to Ball (1941), the 'thickening ring' in arborescent palm stems takes its origin as tiered layers unlike a true cambium; this region, through its activity at subjacent distances from the shoot apex, results in the raising of the stem surface above the level of the apex. The 'thickening ring', according to him, outweighs the apical meristem in extent and importance in so far as the quantum of girth increment is concerned. On the whole, from the point of view of origin, the palm stem in the opinion of Ball is heterogeneous.

This brief summation of pertinent literature on the anatomy of palm stems clearly expresses the inadequacy of clear understanding of the mechanism involved. Although the scope of the present study is to understand the limits of variability in regard to certain cells and tissues and, if possible, to unearth trends or modes of their behaviour, the significance of data in discussions relating to the nature of the arborescent habit in palms has also been attempted to the extent possible.

MATERIAL AND METHODS

A 30-foot tall and about 50-year old trunk of *Phoenix sylvestris* was available for analysis. The tree had been tapped twice for toddy at levels between 26 and 30 feet from the ground. This part of the stem was not selected for study on account of the possible effects of tapping on the subsequently formed tissues. One-inch discs were cut, at regular intervals of two feet, from the ground level. Two methods of sampling were employed:

First method.—The geometric centre of the disc was fixed and a radial strip of about one inch width was sawed off (Text-Fig. 1). A one inch length from the centre (region III) and a half inch length from the periphery (region O) were removed from this strip. Two blocks were selected at equal intervals from the remaining radius (regions I and II). Splints for macerations were obtained from the outer tangential face of blocks O, I and II, and from the inner tangential face of block III. 50 vessel members of the late metaxylem and 100 fibres from the sheathing sclerenchyma of the vascular bundles were measured at random from each region. Thus, on the whole, 4,550 vessel members and 9,100 fibres have been measured from 13 discs. The outlines of the fibro-vascular bundles from transections of individual blocks were traced on paper with the aid of camera lucida, and the respective areas were measured by using a planimeter. Five fibro-vascular bundles from each block were taken at random for this purpose in order to arrive at the mean values. This method of sampling was repeated for the opposite radius of the stem also and it was seen that there was no



TEXT-FIG. 1. Diagrammatic sketch indicating the different regions, O, I, II and III (hatched areas) from which measurements were taken.

significant difference between corresponding values along opposite radii. Therefore, the final values given in the text and tables are the averages of the corresponding regions of opposite radii.

Second method.—In order to check the results thus obtained, another method of random sampling was also tried. The material for maceration was taken from a disc from the 10-foot level of the stem: splints were obtained from 30 random points on the disc, covering the entire cross-sectional area. The values measured through this method confirmed those obtained through the first method.

DISCUSSION OF DATA

Distribution of fibro-vascular bundles per unit area.—The distribution pattern of the fibro-vascular bundles in *Phoenix sylvestris* recalls the general condition known for monocotyledons. In the central part of the stem (region III), the bundles are more widely separated by the intervening non-vascular ground tissue, and in the peripheral part

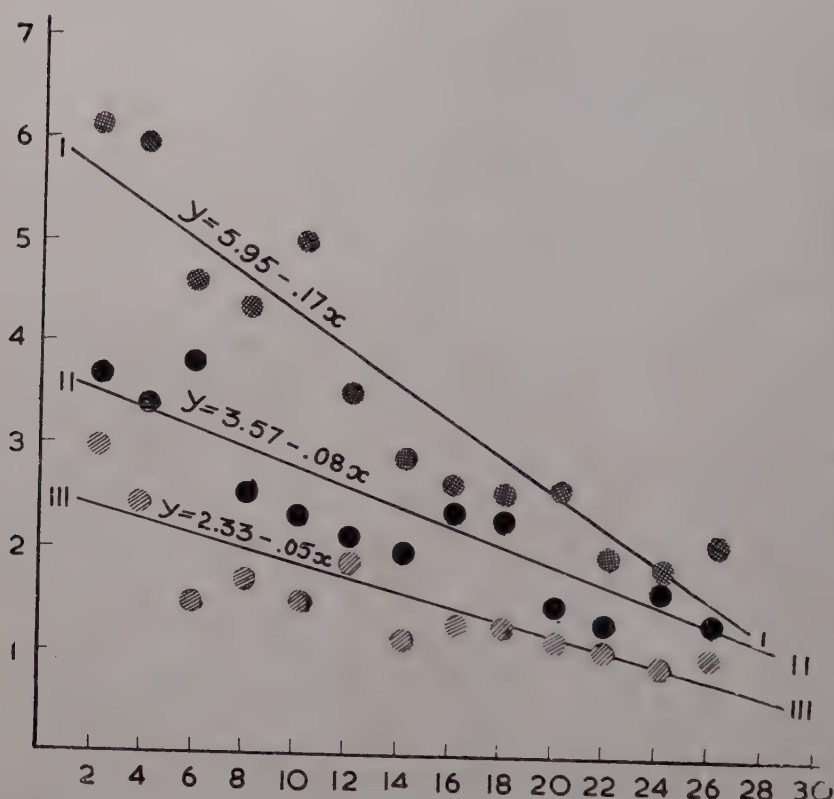
(region O) they are more densely aggregated, while in the area in between a graded condition prevails (Table I). This pattern of distribution repeats itself at all levels of the stem and is further confirmed by the fact that there exists a positive correlation ($+ \cdot 51$) between the distance from the periphery and the number of fibro-vascular bundles per unit area tending to increase from base up to a level of 18 feet, thus reaching a maximum at this height. Thereafter the values decrease at successive heights. As may be judged from the mean values, the difference between regions I and II is far greater than between regions II and III.

TABLE I

*Showing the distribution of fibro-vascular bundles per unit area
($\cdot 06$ sq. inch)*

Height in feet	Region I	Region II	Region III
26	29	15	13
24	30	17	15
22	31	15	15
20	28	20	15
18	41	24	20
16	34	18	16
14	32	19	14
12	23	16	14
10	30	15	14
8	35	18	14
6	24	18	13
4	20	12	8
2	22	14	13
Mean	29 ± 1.1	17 ± 1.1	14 ± 1.0

Fibro-vascular ratio.—The ratio between the transectional area of the fibrous cap and that of the vascular tissues exhibit a striking variability. The bundles in region I bear relatively a higher ratio, in general, than those of the bundles situated towards the interior. However, in a majority of cases, the ratios of region III are lower than those of region II (Text-Fig. 2; Table II). Thus, there is considerable evidence to conclude that there has been a rather gradual transition of the ratios from the periphery towards the centre. When the ratios of the three regions are considered in relation to the height of the stem, a gradual but significant decrease is noted from bottom upwards. However, the slope of decrease is more rapid in region I than in regions II and III (Text-Fig. 2).



TEXT-FIG. 2. Graph showing the relationship between the fibro-vascular ratio and the height of the trunk. The Roman numerals indicate the regions, I, II and III (compare Text-Fig. 1).

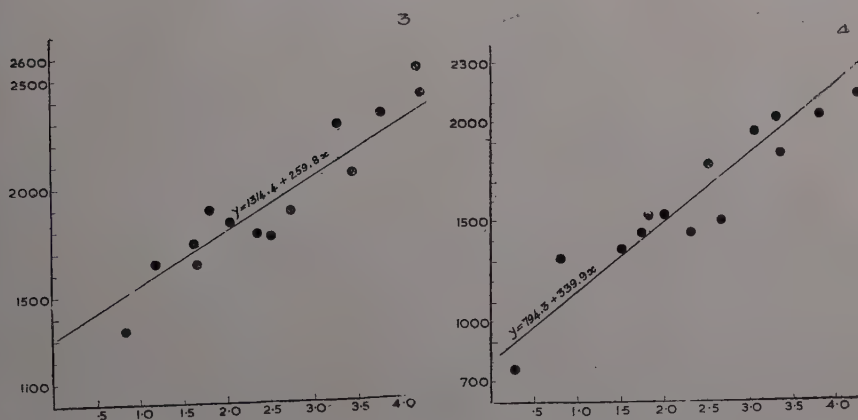
Length of vessel and fibre along the radius of the stem.—The vessel length shows a highly significant behaviour in relation to the radius of the disc, the longest vessel members occurring along the central axis of the stem. This trend is remarkably well expressed by data obtained through the analysis of entire disc following the second method of sampling as described earlier. From the centre towards the periphery, there is a highly significant decrease in the average length of vessels (Text-Fig. 3). A parallel trend is evident in the behaviour of the fibre length as well (Text-Fig. 4).

Length of vessel and fibre along the height of the stem.—The average length of vessel members and of fibres undergoes significant shortening from the base to the top of the stem along all the four regions, O, I, II and III (Table III; Text-Figs. 5 and 6). It must also be noted, that the trend varies in degree among the different regions. Thus, both in the case of vessel members and fibres, the regression values are in the increasing order from region III to region O, as may be seen from

TABLE II

Showing fibro-vascular ratios (cap area/vascular area)

Height in feet	Region I	Region II	Region III
26	2.5	1.8	1.4
24	1.9	1.8	1.0
22	2.1	1.2	1.1
20	2.7	1.5	1.2
18	2.7	3.0	1.3
16	2.3	2.6	1.3
14	2.8	1.7	1.1
12	3.6	1.9	1.9
10	5.0	2.4	1.6
8	4.3	2.7	1.7
6	4.6	3.8	1.5
4	6.0	3.3	2.2
2	6.1	3.6	3.0



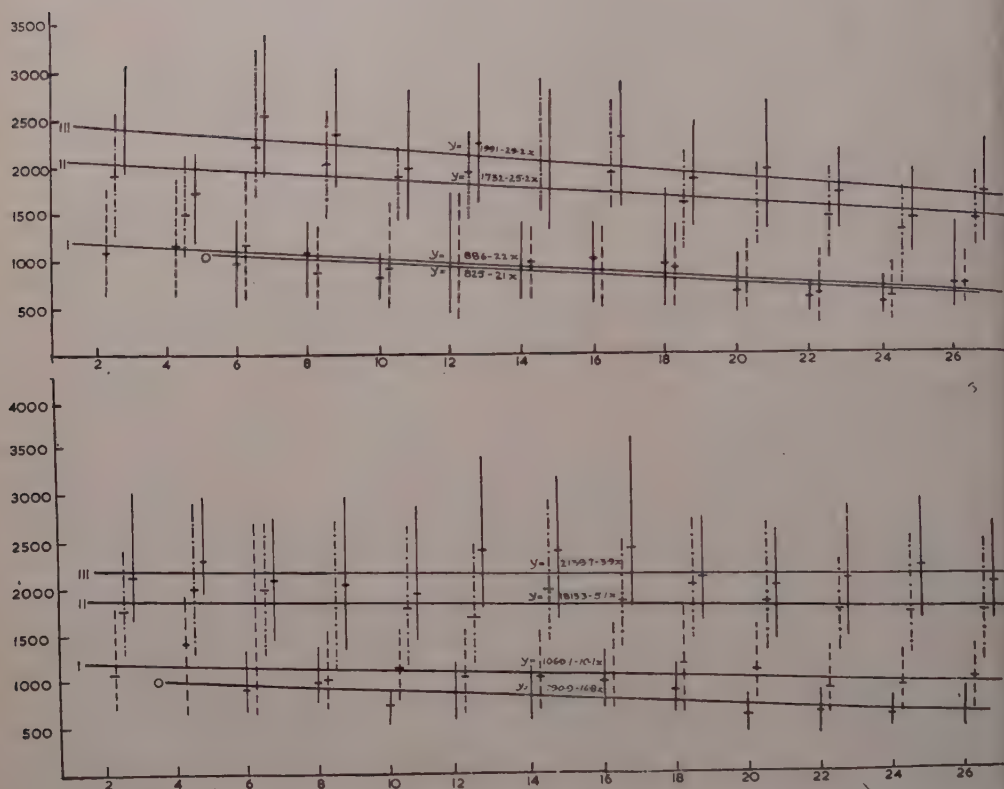
TEXT-FIGS. 3 and 4. Fig. 3. Graph showing the correlated relationship between the fibre length and the radial distance within the disc taken from the 10-foot level of the stem. Fig. 4. Graph showing the correlated relationship between the vessel length and the radial distance within the disc taken from the 10-foot level of the stem.

the respective values recorded on the regression line (Text-Figs. 5 and 6). Between the vessel on the one hand, and the fibres on the other, the former exhibits a more pronounced degree of regression.

TABLE III
Showing the variation in the length of fibres and vessels in relation to the height of the trunk in regions O-III

Height in feet from bottom to top	Region O				Region I			Region II			Region III		
	Mean length in micra	Standard error	Measure of significance	Mean length in micra	Standard error	Measure of significance	Mean length in micra	Standard error	Measure of significance	Mean length in micra	Standard error	Measure of significance	
2	..	..		1061	10.88	FIBRES	1760	16.96		2112	28.13	4.2	
4	..	..		1410	18.88		16.1	1982	23.04	7.7	2294	32.62	4.4
6	918	14.24		1139	12.19		12.1	1888	20.48	3.1	2083	34.56	1.2
8	995	16.48	3.1	1006	11.84		7.8	1814	20.44	2.5	2029	36.04	2.2
10	742	11.17	12.7	1136	11.52		7.8	1762	24.64	1.7	1933	32.32	8.8
12	851	14.94	5.8	1026	11.84		6.6	1662	18.24	3.2	2374	37.96	.05
14	829	13.22	1.1	1035	11.20		.55	1958	20.73	10.7	2371	35.32	.18
16	982	12.42	8.4	1037	14.08		.11	1837	20.54	4.1	2381	40.32	6.1
18	886	12.70	5.4	1162	12.48		6.6	1995	19.42	5.6	2064	34.68	2.04
20	618	8.42	17.6	1090	10.24		4.4	1803	19.33	7.1	1971	30.84	1.8
22	640	9.92	1.9	898	9.76	13.6	1720	16.22	3.3	2048	27.46	3.1	
24	618	8.83	1.6	918	7.64	1.6	1691	17.89	1.2	2170	28.80	4.8	
26	621	10.46	.22	981	9.92	5.1	1701	17.18	.40	1987	24.96		

2	..	1075	30.10	VESELS	1853	29.16	10.7	2387	40.92	13.6
4	..	1203	25.70	3.3	1482	18.85	17.7	1725	26.14	12.7
6	30.72	1153	46.40	.92	2189	35.07	3.7	2515	56.22	3.2
8	28.96	866	20.40	5.6	2016	29.33	4.2	2304	33.04	6.3
10	15.00	918	19.22	1.8	1867	19.79	1.6	1962	42.24	3.9
12	37.52	941	20.29	.82	1923	27.91	2.1	2214	51.08	3.2
14	29.52	962	20.30	.73	2006	26.83	3.1	2003	41.34	4.6
16	34.54	845	20.84	4.02	1901	22.51	10.3	2262	38.58	7.7
18	34.56	893	16.74	1.8	1581	22.75	.20	1843	37.94	1.3
20	23.60	794	15.43	4.3	1587	19.23	5.2	1923	45.44	4.4
22	12.90	603	13.70	9.2	1434	21.84	4.8	1677	33.70	6.1
24	13.02	565	14.54	1.9	1282	23.04	3.9	1402	28.20	6.9
26	28.70	480	13.80	6.7	1088	16.39		1120	29.44	



TEXT-FIGS. 5 and 6. Graphs showing the negatively correlated behaviour of the vessel length (Fig. 5) and fibre length (Fig. 6) in regions O, I, II and III in relation to the height of the stem from bottom to top, as shown by the linear regression lines; the lines parallel to the vertical axis indicate the gamut of variability of the cell types at the corresponding heights. The mean values of the range have been indicated by horizontal bar on the vertical lines. Where bars are not indicated, the regression line cuts across the mean value.

There appears to be a high degree of negative correlation between the length of vessel member and the height of the stem. In other words, the length of vessel member decreases as the height of the stem increases. Furthermore, the correlation coefficients are decidedly higher in regions O and I, while the corresponding values are relatively lower in regions II and III (Table IV). The fibre length is negatively correlated in regions O and I, while no such relationship occurs in regions II and III. It is also seen that there is a high degree of correlation between the vessel length and fibre length along the height of the trunk in region O ($+ \cdot 94$) and in region I.

Vessel length and the number of bars.—The data given in Table V suggest that the length of the vessel member is correlated with the number

TABLE IV

Showing the correlation coefficients between the length of vessel members and fibres to the height of the stem

	Region O		Region I		Region II		Region III	
	<i>r</i>	Standard error	<i>r</i>	Standard error	<i>r</i>	Standard error	<i>r</i>	Standard error
Vessel ..	-.81	.049	-.88	.032	-.65	.082	-.67	.078
Fibre ..	-.75	.044	-.59	.065	-.35	.088	-.18	.097

(+ .82); but the values fall to insignificance in region II (+ .22), and region III (+ .11).

of bars in the scalariform perforation plate. The vessel members in region O possess significantly a larger number of bars as compared with those of regions II and III, wherein the cells are decidedly longer; a similar relation is also seen as compared with region I where the length of the perforate tracheary cells more or less approximate with those of region O. In other words, the largest number of bars (10-17) per perforation plate are associated with relatively shorter vessel members of region O and a far fewer number of bars (1-5) per perforation plate are related to the comparatively longer vessel members of the other three regions.

The data in Table V also indicate that the number of bars in regions I, II and III represent an abrupt decrease as compared with region O. This situation raises important questions as to the factors involved in the expression of this phenomenon. In the secondary xylem of dicotyledons, it is well known that the longer vessel members generally possess a larger number of bars. In *Phoenix sylvestris* this relationship has become reversed; that is, the longer vessel members of regions II and III possess fewer number of bars (1-5) as compared with the regions O and I, which possess shorter vessel members with a larger number of bars (10-17). In regions O and I, however, it must be emphasized that the vessel length has remained approximately the same, but the number of bars in region I has fallen from an average of 14 to 3. Therefore, a pertinent question to be raised at this juncture would be—what is it that causes such a drastic reduction in the number of bars in region I, although the length of the vessel member has remained more or less the same?

The answer to be given at this moment could only be a conjecture. Region O, being the peripheral zone of the stem, it is likely that a very large percentage of the vascular bundles—though not all—directly

TABLE V

Showing the length of vessel members and the number of bars of the scalariform perforation plates

Height in feet	Region O		Region I		Region II		Region III	
	Vessel length μ	Number of bars	Vessel length μ	Number of bars	Vessel length μ	Number of bars	Vessel length μ	Number of bars
26	704	12	699	2	1392	2	1667	3
24	521	11	565	4	1282	3	1402	2
22	579	10	603	3	1434	3	1677	2
20	650	14	794	5	1587	2	1923	2
18	938	14	893	4	1581	2	1843	2
16	992	14	845	3	1901	4	2262	3
14	938	13	962	4	2006	3	2003	3
12	938	17	941	5	1923	3	2214	3
10	819	14	918	3	1867	2	1962	4
8	1062	14	866	3	2016	3	2304	5
6	938	16	1153	3	2189	3	2515	4
4	..	..	1200	4	1482	2	1725	1
2	..	..	952	3	1853	4	2387	4

supply the leaf. Therefore, these regions correspond to the subjacent levels of leaf insertion, where a least degree of elongation may be expected. The vessels in these regions, likewise, possess shorter vertical dimension. It is also probable that such "arrested" vessel members undergo maturation retaining the original number of bars with which the vessel member started differentiation in contrast to those that are situated towards the interior of the stem (regions I, II and III), which are, however, accompanied with a reduction in the number of bars during differentiation.

The correlation coefficients presented in Table VI indicate that, in general, there is a negative correlation between the vessel length and the number of bars along the radial axis.

TABLE VI

Showing correlation coefficients between vessel length and number of bars along the radial plane

Height in feet	Correlation coefficient	Standard error
26	—·50	·123
24	—·75	·094
22	—·64	·109
20	—·80	·085
18	—·65	·108
16	—·47	·125
14	—·66	·106
12	—·31	·135
10	—·63	·109
8	—·36	·132
6	—·62	·111
4	—·62	·111
2	—·77	·090

The regions O and III exhibit a positive correlation between the vessel length and the number of bars along the height of the stem, whereas regions I and II do not show any correlation at all (Table VII). The explanation for this anomaly will have to be looked for in the peculiar histological feature of *Phoenix sylvestris*. This feature pertains to the occurrence of vessel members with a reticulate perforation plate. These occur essentially in regions I and II, and very occasionally in regions O and III (Table VIII). Thus, in the former two regions the occurrence of reticulate perforation plates are in the order of 13% and 20% respectively; and in the latter two regions, it is 2% and 6% respectively. Perhaps the high percentage of vessels with reticulate perforation plates in regions I and II may account for the low value of correlation. If viewed developmentally, the reticulate perforation plate appears to be a transition stage leading toward the attainment of the simple porous condition.

Trends of structural variability in the stem of Phoenix sylvestris in relation to those of arborescent gymnosperms and dicotyledons.—The preceding account expounds the quantum of variability within a single palm stem and underlines that apart from the variability in the dimensions

TABLE VII

Showing the correlation coefficients between the vessel length and the number of bars along the height of the stem

Region O		Region I		Region II		Region III	
<i>r</i>	Standard error	<i>r</i>	Standard error	<i>r</i>	Standard error	<i>r</i>	Standard error
+·71	0·99	+·09	·141	+·35	·132	+·71	·099

TABLE VIII

Showing the occurrence of different types of perforation plates at various levels and regions of the stem

Height in feet	Region O			Region I			Region II			Region III		
	Sc	Rt	Pr	Sc	Rt	Sc	Sc	Rt	Pr	Sc	Rt	Pr
26	50	0	0	45	4	1	41	7	2	50	0	0
24	50	0	0	44	6	0	44	4	2	45	1	4
22	50	0	0	40	10	0	45	5	0	30	20	0
20	50	0	0	41	8	1	38	12	0	46	4	0
18	50	0	0	40	10	0	44	6	0	45	5	0
16	49	1	0	34	15	1	27	23	0	50	0	0
14	50	0	0	38	12	0	38	9	3	50	0	0
12	49	1	0	50	0	0	33	17	0	50	0	0
10	48	0	2	43	7	0	40	10	0	50	0	0
8	50	0	0	41	9	0	27	23	0	50	0	0
6	48	0	2	50	0	0	39	11	0	47	3	0
4	33	10	7	42	3	5	50	0	0	46	4	0
2	50	0	0	48	2	0	48	2	0	48	2	0

Sc = scalariform; Rt = Reticulate; Pr = Porous.

of certain cell types like the vessel and fibre, the measurable features of tissues like area of fibro-vascular bundles and fibro-vascular (f/v) ratio also show significant variation. These variations do not appear to be haphazard but conform to certain specific trends. Thus;

- (1) the number of fibro-vascular bundles per unit area increases from centre to periphery and from bottom to top up to nearly two-thirds the height of the stem;
- (2) the f/v ratio decreases not only from periphery to centre but also from bottom upwards; and
- (3) the fibres and vessel members decrease in length from bottom to top and from centre to periphery throughout the stem.

It may be incidentally mentioned that identical trends have been discovered in the stems of *Cocos nucifera* and *Borassus flabellifera*, both possessing similar morphological type of arborescent habit as that of *Phoenix sylvestris* (Ganapathy, 1959). Therefore, these trends appear to be reliable and widespread at least in arborescent palm stems of a more or less cylindrical shape where there has been a total suppression of internodal elongation. To compare or contrast these trends of anatomical variations to those established for arborescent gymnosperms and dicotyledons may be objectionable from several points of view. Yet, it appears to be a profitable venture to do so in order to emphasize the divergent trends in the two categories of arborescent plant groups.

In both the categories of plants—irrepective of the methods of vertical extension and radial types of growth—the cells that are being continuously added on to the stem are subjected to significant variations conforming to definite trends. In other words, age appears to exert enormous influence on the dimensions of newly formed cells. In woody gymnosperms and dicotyledons, the length of the perforate and imperforate tracheary cells increase rapidly from centre outwards of a stem or branch for a varying number of years depending upon the taxon (compare Sanio's first Law). In *Phoenix*, as also in *Borassus* and *Cocos*, the average length of vessels as well as of non-vascular fibres decreases from centre towards periphery. From bottom to top also, the length of these cell types decreases gradually although in *Cocos* there is a slight initial increase prior to the commencement of fall in length. In the majority of gymnospermous and dicotyledonous trees, on the other hand, a gradual increase is noticed from bottom to the top of the stem, the maximum length being attained at a specific vertical level of the trunk and decreasing thereafter (compare Sanio's second Law). In woody dicotyledons, there is a significant correlation between the length of vessel members and the type of perforations on the end walls (Frost, 1930): perforations of longer vessels possess a larger number of bars and *vice versa*. In *Phoenix*, this trend appears to be reversed, the vessel members in a specific region of the stem possessing shorter linear dimensions and a larger number of bars. This phenomenon in *Phoenix*, however, appears to be due to developmental factors and perhaps should be excluded from comparison.

General considerations on the modus operandi of growth in thickness of the palm stem.—The mechanism of increase in the girth of arborescent palm stems has never been clearly understood. In recent years, Cheadle (1937) and Ball (1941), working on the woody Liliaceae, Amaryllidaceae,

and Palmae respectively, agree that the meristem bringing about increase in the diameter of the stem is what has been designated as the "thickening ring". This tissue is unlike the vascular cambium of gymnosperms and dicotyledons in the manner of origin, in the method of cutting off of the derivatives, and location. The organization of the derivative cells and tissues are also diversified in the case of the cambium and in the case of the "thickening ring". Therefore, the similarity between these two tissues is limited only to their basic meristematic activity. If there are any other deep-seated structural similarities, we do not know for certain.

A more strictly comparable tissue between gymnosperms and dicotyledons on the one hand, and palms on the other, appears to be the primary vascular bundles of the former group with the vascular bundles of the latter. In both these categories of plants, the ontogenetic succession of tracheary cells from the proto- to metaxylem is fundamentally similar (Bailey, 1944; Cheadle, 1953); so also their respective relationships in regard to their linear measurements. In gymnosperms and dicotyledons, "there is an abrupt and conspicuous decrease in length of tracheary cells in passing from the last-formed primary xylem to the adjacent first formed secondary xylem" (Bailey, 1944). It is significant that such a zone in the stem of the palms at any rate is wholly absent. In other words, the subsequent interpolation of cambial activity in the stems of gymnosperms and dicotyledons appears to have created a conspicuous and abrupt shift in the course of variability of anatomical structure of the vascular tissues. In the stems of *Phoenix* and of *Cocos* and *Borassus* (Ganapathy, 1959), the origin and functioning of the "thickening ring" has *not* brought about such a hiatus; on the other hand, the vascular tissues derived through the meristem clearly exhibit a *continuation* of the trends that are initiated in the corresponding tissues formed earliest in ontogeny. Thus, the regression lines drawn for the type of variation in the length of vessel members (Text-Fig. 3) indicates that the growth in thickness of the stem is a uniform and uninterrupted process. Such a uniformity is also present in other cell types and tissues of the palm stem.

Another point that should be mentioned in this connection relates to the nature of the derivative tissues of the cambium and of the "thickening ring". In gymnosperms and dicotyledons, the cell types and tissues that are derived from the vascular cambium are in general morphologically dissimilar to the ones differentiating from the procambium, although in either case, the corresponding cell types may be reduced to the same fundamental category; furthermore, the cambial derivatives never mature into annular or helically thickened tracheary cells. In contrast, in the palm stem, the derivatives of the "thickening ring" for the most part differentiate into cell types and tissues that are morphologically similar to the ones already present in the stem prior to the commencement of the activity of the meristem. That the successively formed tissues furthermore conform to definite trends of behaviour have already been explained.

Considerations such as these suggest that the arborescent palm stem is the ultimate expression of a single source (activity of the shoot apex) unlike those of the woody gymnosperms and dicotyledons, which attain their mature form due to two almost independent, although ontogenetically related, sources (procambium and vascular cambium). The origin and organization of the "thickening ring" appears to have a much more intimate relationship with the method of activity of the shoot apex of palm stems than the relationship that exists between the cambium and shoot apex of arborescent gymnosperms and dicotyledons. In the latter groups, there has been demonstrated an appreciable lag between the origin of procambium and of the vascular cambium; the differentiation of the latter is directly related to the procambium and not to the terminal meristem. In *Phoenix*, and possibly in other related palm stems, no such lag is discernible; the attainment of stem girth is one continuum from the time of origin of the primary structure. Thus the shoot apex intimately merges itself in the organization of the thickening ring which, thereby, produces an exaggerated primary body.

Significance of the structural variability in the identification of the form-genus Palmoxylon.—From India alone, nearly 18 species of the Cretaceous-Tertiary Palmoxyla have been described (for literature, see Rao, 1958). The important criteria employed to distinguish and identify the "species" are (a) extent and nature of 'cortical', 'subdermal', and 'dermal' and 'central' zones, (b) orientation of vascular bundles, (c) frequency of bundles per unit area, (d) f/v ratio of bundles, and (e) morphological type of bundles based mainly on the number of large metaxylem vessels. It has been shown in the present study that characters included in (b), (c), and (d) are subject to rather wide fluctuations within a single stem. Therefore, data obtained through fragmentary specimens of Palmoxyla, in most instances, represent only one phase in the wide gamut of variability, and therefore identifications based upon such restricted data is quite often unreliable. Ganapathy (1959) has likewise shown for *Cocos* and *Borassus* that features included in items (a) and (e) fail to serve as dependable diagnostic criteria. The present study has furthermore shown the range of variability that occurs in regard to the cell dimensions (vessels and fibres) and to the type of vessel perforations.

It is but natural that in the absence of more reliable diagnostic criteria, the above features are largely being employed in the identification of the Palmoxyla, although many botanists are quite aware of the provisional nature of the "species" that they propose. However, there has also been a parallel tendency to rely too much on these criteria and thereby unwarrantedly multiply the number of "species". It is with the purpose of discovering new and relatively more dependable diagnostic criteria that Kaul (1935) initiated studies on the nature and distribution of ground tissue in the stems of palms. Unfortunately, Kaul's detailed and final observations have not yet been published and therefore a discussion on the features suggested by him cannot be given at this juncture. However, we are inclined to remark here that even the ground tissue exhibits rather widely variable morphological

features within a single stem. As will be shown in a subsequent paper, the pattern, extent and behaviour of this tissue in *Phoenix* are subject to a range of variability.

Merely because a particular feature happens to be a variable one, it should not be implied that such a feature cannot be made use of as reliable means of identification. Such features, although many a time valueless by themselves, become significant when their relationship to a trend is realized. In fact, one of the main purposes of the present study has been to understand the limits and patterns of variability of observable and measurable features, and to outline such trends. Preliminary data on hand suggest that among arborescent palms the modes and limits of variability appear to be diverse in different groups, and that specific combinations of trends do not overlap the diverse categories of arborescent palm stems. Therefore, it is likely that thorough knowledge along these lines would eventually provide a basis to recognize with reasonable accuracy several morphological types of palm woods.

SUMMARY

A 30-foot trunk of *Phoenix sylvestris* has been analyzed in order to find out the structural variability within a single stem.

The fibro-vascular bundles at any level of the stem exhibit a graded distribution, more widely spaced in the centre and densely aggregated at the periphery. The number of the fibro-vascular bundles per unit area in any region of the disc tends to increase from the bottom up to about two-third height of the stem; at subsequent levels, the number in the corresponding regions shows a slight reduction. The fibro-vascular ratio decreases not only from the periphery towards the centre of the stem but also from bottom upwards.

The vessels and fibres show a statistically significant increase in length from the periphery towards the centre of the stem at any given level; from bottom towards the top, however, the length of these cell types show a decreasing trend. The regression is marked in the peripheral regions of the stem and exhibits a graded decrease towards the centre. Between vessels and fibres, the trend in the former is more pronounced.

Significant negative correlation exists between the vessel length and the number of bars in the perforation plates, longer vessel members possessing fewer number of bars than the shorter ones.

With decreasing trend of vessel length in the peripheral and central regions (regions O and III) along the vertical axis is correlated with the reduction in the number of bars in the perforation plate. However, such a correlation is absent in the intervening regions I and II. This may possibly be due to the high frequency of reticulate perforation plates occurring in these parts.

After comparing and contrasting the trends of variability exhibited by certain anatomical features between the wood of *Phoenix* on the

one hand, and of arborescent gymnosperms and dicotyledons on the other, the significance of some of the trends in relation to the method of growth in the thickness of palm stems is discussed. It is suggested that the origin and organization of the "thickening ring" is a continued activity of the shoot apex, producing an exaggerated development of the primary body.

The significance of structural variability in the identification of *Palmoxyla* is discussed. Criteria based on the ranges of anatomical variability, rather than characters gleaned through an examination of isolated and restricted specimens appear to afford reliable clues for diagnosing the different morphological types of palm woods.

ACKNOWLEDGEMENTS

We are grateful to Prof. P. Govindan, Professor of Zoology, Annamalai University, for the benefit of discussion on statistical methods.

REFERENCES

- BAILEY, I. W. 1944. The development of vessels in angiosperms and its significance in morphological research. *Amer. J. Bot.* **31**: 421-28.
- , AND SHEPARD, H. B. 1915. Sanio's Laws for the variation in size of coniferous tracheids. *Bot. Gaz.* **60**: 66-71.
- BALL, E. 1941. The development of the shoot apex and of the primary thickening meristem in *Phoenix canariensis* Chamb., with comparisons to *Washingtonia filifera* Wats. and *Trachycarous excelsa* Wendl. *Amer. J. Bot.* **28**: 820-32.
- BISSETT, I. J. W. 1949 I. Bibliography of references on the variations of tracheids and fibre length and their distribution in angiosperms and gymnosperms. II. Summarized data on the variation of fibre and tracheid length and their distribution in angiosperms and gymnosperms. *Bibliogr. Ser. Div. For. Prod. Aust.* No. 37, 1-10.
- CHALK, L. 1930. Tracheid length with special reference to Sitka Spruce (*Picea sitchensis* Carr.). *Forestry* **4**: 7-14.
- CHEADLE, V. I. 1937. Secondary growth by means of a thickening ring in certain monocotyledons. *Bot. Gaz.* **98**: 535-55.
- , 1953. Independent origin of vessels in the monocotyledons and dicotyledons. *Phytomorphology* **3**: 23-44.
- EICHORN, F. 1895. Untersuchungen über das Holz der Roteiche. *Forstl.-naturw.* **4**: 233-81.
- FROST, F. H. 1930. Specialization in the secondary xylem of dicotyledons. II. Evolution of the end wall of vessel segments. *Bot. Gaz.* **90**: 198-212.
- GANAPATHY, P. M. 1959. Anatomy of Palms. *Doctoral Thesis*, Univ. Madras (unpublished).
- HARTIG, R. AND WEBBER, 1885. *Das Holz der Totbuche*, Berlin.
- * KARSTEN, H. 1847. *Die Vegetationsorgane der Palmaen. Ein Beitrag zur vergleichende Anatomie und Physiologie. Gesammelte Beiträge zur Anatomie und Physiologie der Pflanzen* Berlin 1865, 82-186.

- KAUL, K. N. 1935. A classification of the palms based upon the ground tissue of the stem. *Proc. 22nd Indian Sci. Congr. Calcutta* pp. 285-86.
- VAN MOHL, H. 1845. On the structure of the palm stem. *Rep. Ray Soc.* pp. 1-92.
- MOLDENHAWER, J. J. P. 1812. *Beiträge zur Anatomie der Pflanzen*, Kiel.
- RAO, A. R. 1958. *History of Botanical Researches in India, Burma and Ceylon*. Part III. *Palaeobotany*. Bangalore Press, pp. 1-57.
- SANIO, K. 1872. Ueber die Grosse der Holzzellen bei der gemeinen Kiefer (*Pinus sylvestris*). *Jb. wiss. Bot.* **8**: 401-20.
- SCHOUTE, J. C. 1912. Ueber das Dickenwachstum der Palmen. *Ann. Jard. bot. Buitenz.* **26**: 1-209.
- SPURR, S. H. AND HYVÄRINEN, M. J. 1954. Wood fibre length as related to position in tree and growth. *Bot. Rev.* **20**: 561-75.

* Original not seen.

ON SOME NEW CONCEPTS IN PHYTOSOCIOLOGICAL STUDIES OF GRASSLANDS

I. Dominance Diagrams

BY S. C. PANDEYA *

Science College, Raipur

(Received for publication on February 23, 1960)

INTRODUCTION

INDIA being a tropical country, the ecological conditions differ so widely from those of Europe and America that it becomes difficult to adjust our ecological results into their systems. India experiences a periodic monsoonic climate. Consequently, the vegetation is periodic and every phase has its own development, physiognomy and habitat conditions. We have, therefore, to evolve our own ecological methods. Thus on the basis of practical field difficulties some 'phytosociological concepts' have been changed and others modified. The same are intended to be presented in a series of papers.

DOMINANCE DIAGRAMS

The problem of homogeneity of a plant community, first brought forward by Nordhagen (1922), has received various treatments both from plant ecologists and mathematicians, without being adequately cleared up. Raunkiaer (1918) suggested "Frequency Diagrams" as an expression of the floristic uniformity of a stand. Braun Blanquet (1932) supported the idea of these diagrams as an 'approximate expression of the homogeneity'.

While investigating the ecology of some grasslands of Madhya Pradesh, the author observed that the degree of homogeneity actually present 'in abstract' could not be expressed by Raunkiaer's 'Frequency Diagrams'. Obviously Raunkiaer (1918) and Braun Blanquet (1932) have based their idea of homogeneity of vegetation on the assumption that an association is an assemblage of plants which is almost uniform. Gleason (1939), Cain (1947), Pandeya (1953) and Hanson (1958) have given sufficient arguments in favour of an 'abstract association'. Here a plant community is considered uniform only to a reasonable degree. Hanson (1958) opines that plant groupings are not identical, even within a limited area, but they resemble with one another sufficiently and yet differ sufficiently from other groupings so that they may be classified together in one kind, type, or abstract community.

* Present Address : Central Botanical Laboratories, 10, Chatham Lines, Allahabad.

In his 'Frequency Diagrams' Raunkiaer noted the frequencies of each species in a small area without counting individuals or noting cover. He expressed the results in a diagram distributing the number of species into 5 frequency classes. According to his 'law of frequency' the floristic uniformity varies directly with the values for frequency class E. The reason for the failure of getting the validity of his diagrams in the grass-land studies seems apparent. This is because the 'Frequency Diagrams' do not account for the cover of a particular species, which in most cases is responsible for the homogeneity of a stand 'in abstract'. It is, of course, accepted that 'frequency index' which is the proportion of samples in which a given species occurs is related to 'dispersion of population'. But the same is not proportional to the cover of a species, at least in grasslands. Thus a single species may dominate an area with 80 to 90% of cover making the stand homogeneous 'in abstract'. Yet according to Raunkiaer's 'Frequency Diagrams' the same stand would appear absolutely heterogeneous with a very small frequency class E. 'Frequency Diagrams' are, therefore, helpful only in judging the similarities between different associations and fail to account for the abstract homogeneity present in the same association. In order to overcome these difficulties the following new method is being proposed. The diagrams constructed on the basis of this method have been named as 'DOMINANCE DIAGRAMS'. Dominance diagrams essentially include the cover by each species in addition to number of species belonging to a particular frequency class.

METHOD OF CONSTRUCTING DOMINANCE DIAGRAMS

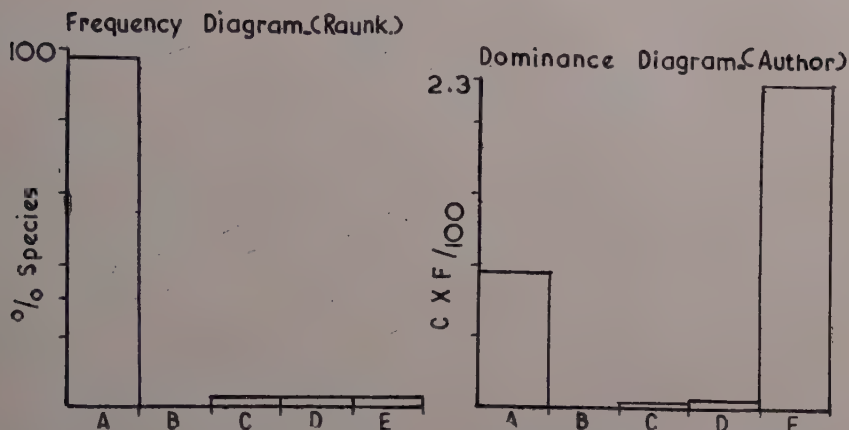
First, all the species found by random sampling in a stand are divided into Raunkiaer's 'frequency classes', viz., A, B, C, D and E. Next the percentage of area covered by all the species (expressed in percentage of the total) falling in a particular frequency class is multiplied by percentage number of species present in that class.

Dominance Diagrams are then drawn by plotting the fraction represented by the product of percentage-cover \times percentage-number of species against each frequency class.

ADVANTAGE OF 'DOMINANCE DIAGRAMS' OVER RAUNKIAER'S FREQUENCY DIAGRAMS

'Dominance' and 'Frequency' Diagrams of *Themeda quadrivalvis* association of Sagar (M.P.) are presented here for comparison (Text-Fig. 1). 80 to 95% of the association is occupied by a single species *Themeda quadrivalvis* O. Ktze. making the association homogeneous to a reasonable degree. This homogeneity actually present in the association 'in abstract' cannot be accounted for from the Raunkiaer's 'Frequency Diagram' (Text-Fig. 1). 'The abstract homogeneity' is, however, very well shown by the 'Dominance Diagram'.

Following conclusions may be drawn in favour of 'Dominance Diagram':—



TEXT-FIG. 1. 'Frequency Diagram' (after Raunkiaer) and 'Dominance Diagram' of *Themeda quadrivalvis* O. Ktze. association of Sagar (Madhya Pradesh). A, B, C, D, and E are the Raunkiaer's Frequency Classes.

1. Unlike 'Frequency Diagram' the space occupied by species falling in each frequency class is also shown by 'Dominance Diagram'. It may be mentioned here that "the use of 'frequency' as a single determination in the analytical procedure has proven unsatisfactory"—Oosting (1956). It appears that frequency in co-ordination with percentage cover is fundamental for understanding the structure of at least a grassland community.

2. The degree of homogeneity present in a stand or an association can be clearly made out from these diagrams. Since, in general, higher the value for class E, the more homogeneous will be the stand. It has been observed that if the value of $(E + D)/(B + C) =$ less than 1, the stand is heterogeneous. The degree of homogeneity has been found to increase with increase in the value above 1.

3. If the value for class A is very high it is due to the presence of many 'accidentals'. Actually the presence of 'accidentals' does not hamper in any way, the 'abstract homogeneity' in a stand since they occupy very less area and occur in lowest frequency class.

SUMMARY

India being a tropical country, the ecological conditions differ so widely from those of Europe and America that it becomes difficult to adjust our ecological results into their systems. Thus on the basis of practical field difficulties some 'phytosociological concepts' have been changed and others modified. The same are intended to be presented in a series of papers.

The present paper deals with the expression of 'homogeneity' of plant communities. The 'abstract homogeneity' actually present in grassland associations could not be expressed by Raunkiaer's (1918)

'Frequency Diagram', since he has included only the frequency of species without counting individuals or noting their cover. In light of these difficulties and noting the periodic nature of grasslands in India, a new method of "DOMINANCE DIAGRAM" has been proposed. This new method essentially incorporates cover by each species in addition to the number of species belonging to a particular frequency class. The present method and the Raunkiaer's one have been compared. Advantages and accuracy of the proposed method have been given. A mathematical expression of the 'homogeneity' has also been proposed.

ACKNOWLEDGEMENTS

I am greatly indebted to Prof. R. Misra, Head of the Department of Botany, Banaras Hindu University, for his very kind guidance and constant encouragement during the course of this study. I am also thankful to Mr. T. S. Trivedi for his helpful discussions.

REFERENCES

- BRAUN BLANQUET, J. 1932. *Plant Sociology*. Translated by G.D. Fuller and H. S. Conard, McGraw-Hill Book Co., Inc., New York.
- CAIN, S. A. 1947. The characteristics of natural areas and factors in their development. *Ecol. Monogr.* **17**: 185-200.
- GLEASON, H. 1939. The individualistic concept of plant association. *Amer. Midl. Nat.* **21**: 92-110.
- HANSON, H. C. 1958. Principles concerned in the formation and classification of communities. *Bot. Rev.* **24**: 65-127.
- NORDHAGEN, R. 1922. Om Homogenitet konstans og minimiareal. *Nyt Mag. Naturv.* **61**.
- OOSTING, H. J. 1956. *The Study of Plant Communities*. W. H. Freeman & Co., San Francisco.
- PANDEYA, S. C. 1953. An ecological study of the grasslands of Sagar (M.P.). *Doctoral Thesis*, Saugar University (Unpublished).
- RAUNKIAER, C. 1918. Recherches statistiques sur les formation végétales. *Biol. Medd., Kbh.* **1**.

ON SOME NEW CONCEPTS IN PHYTOSOCIOLOGICAL STUDIES OF GRASSLANDS

II. Community Coefficient ($F \times C$) ICC.

BY S. C. PANDEYA

Science College, Raipur

(Received for publication on February 23, 1960)

INTRODUCTION

FOR evaluating the differences and similarities between two stands or two communities on statistical basis 'Community Coefficient' has been suggested. The concept was originally formulated by Jaccard (1912) and subsequently developed by Gleason (1920) and Kulczynski (1937) Gleason used 'frequency index' in place of 'just occurrence' as used by Jaccard. He thus obtained FICC (Frequency Index Community Coefficient). Gleason's method gave him high figures (above 80), if the two stands under examination are similar. The lower this coefficient is the more dissimilar the stands are.

As has been pointed out by Gates (1949) the FICC method of comparison is open to criticism since no distinction is made between a species which occurs in small numbers in a quadrat and one which occurs in large numbers. It may be argued here that number of individuals per species alone may not be sufficient because a species may occur with the same number in two stands and yet may have different cover. Therefore, it is essential to have the relative importance of each species for comparing any two stands. For this the following modification in the method is being proposed:

METHOD

The new method is being called as:—

“(F×C) ICC: [(Frequency × Cover) Index
Community Coefficient”]

In this method instead of 'frequency index', 'frequency × cover' index has been used. To compare two stands five columns are set. In the first, the fraction represented by the product of 'F × C' of each species that occurs in the first stand only is put; in the fifth column the fraction of 'F × C' of the species that occur only in the second stand is put; in the second and third columns are put fractions of 'F × C' of the species common to both stands; while in the fourth are calculated

TABLE

Statistical comparison between stands 1 and 4 of *Eulalia-Cymbopogon*

SPECIES	FICC METHOD		
	ONLY 1	COMMON IN 1 & 4	ONLY 4
<i>Eulalia trispicata</i> ..	..	100 100	..
<i>Cymbopogon martini</i> ..	..	100 100	..
<i>Alloteropsis cimicina</i> ..	..	10 10	..
<i>Arundinella nepalensis</i> ..	10	..	..
<i>Heteropogon contortus</i> ..	..	60 40	..
<i>Dichanthium annulatum</i> ..	..	40 30	..
<i>Dichanthium caricosum</i> ..	..	10 10	..
<i>Tragus biflorus</i> ..	10	..	..
<i>Bothriochloa pertusa</i> ..	..	..	10
<i>Setima nervosum</i> ..	10	..	..
<i>Andropogon pumilus</i> ..	..	..	10
<i>Themeda quadrivalvis</i> ..	..	..	10
<i>Themeda tremula</i> ..	10	..	..
<i>Sporobolus diander</i> ..	..	..	10
<i>Amphilophis ischaemum</i> ..	..	..	10
<i>Saccharum spontaneum</i> ..	..	10 10	..
<i>Digitaria royleana</i> ..	..	10 10	..
<i>Tripogon lisboae</i> ..	10	..	..
<i>Apluda mutica</i> ..	..	..	10
<i>Pennisetum hohenackeri</i> ..	10	..	..
<i>Setaria glauca</i> ..	..	10 10	..
<i>Urochloa panicoides</i> ..	10	..	..
<i>Heylandia latibrosa</i> ..	..	10 10	..
<i>Alysicarpus rugosus</i> ..	..	10 10	..
<i>Eremopogon foveolatus</i> ..	50	..	..
TOTALS ..	120	710	70

 $\frac{1}{2}$ of common 355 $\frac{1}{2}$ of common + 1 + 4 .. 545

$$\begin{aligned}
 \therefore \text{FICC} &= \frac{\frac{1}{2} \text{ of common}}{\frac{1}{2} \text{ of common} + 1 + 4} \times 100 \\
 &= \frac{355}{545} \times 100 \\
 &= 64.9
 \end{aligned}$$

I

association by FICC (after Gleason) and ($F \times C$) ICC (after author)FREQUENCY \times COVER INDEX METHOD

ONLY 1	COMMON IN		DIFF. COMMON	ONLY 4
	1	2		
..	20.00	40.00	20.0	..
..	60.00	21.00	39.0	..
..	0.01	0.01	..	..
0.01	..	..	..	..
..	3.00	4.00	1.0	..
..	4.00	1.50	2.5	..
..	0.01	0.01	..	..
0.01	..	..	..	..
..	..	..	..	0.01
0.01	..	..	..	..
..	..	..	..	0.01
..	..	..	..	0.01
0.01	..	..	..	..
..	..	..	..	0.01
..	..	..	..	0.01
..	0.01	0.01	..	..
..	0.01	0.01	..	..
0.01	..	..	..	..
..	..	..	..	0.01
0.01	..	..	..	..
..	0.01	0.01	..	..
..	0.01	0.01	..	..
2.50	..	..	..	..
2.57	87.07 + 66.57 = 153.64		62.5	0.07

Difference of common 62.50

Difference of common + 1 + 4 65.14

Total of common 153.64

Total of common + difference of common + 1 + 4 .. 218.78

$$\therefore (F \times C) ICC = \frac{153.64}{218.78} \times 100 = 70.6$$

the differences of the fractions of ' $F \times C$ ' of each species common to both stands. All the columns are separately added. Next the second and third columns are added together to give the total of the fractions of ' $F \times C$ ' of common species that occur in both the stands. To obtain the coefficient, the 'total of common' is divided by the 'total of common' plus 'difference of common' (set in column IV) plus I+IV and multiplied by 100, as shown in Table I. In the table are calculated the community coefficient of a grassland association of Sagar (M.P.) as per Gleason's 'frequency index' method and by the present modified method of '(Frequency \times Cover) Index'.

The coefficients by the two methods are: 64.9 and 70.6 respectively.

CONCLUSION

The present modified method, therefore, makes a critical distinction between a species that occurs in small or large areas and thus gives a more accurate degree of comparison.

SUMMARY

1. The paper deals with a modified method of 'Community Coefficient'. The method which was originally proposed by Gleason (1920) is used for evaluating the differences and similarities between two stands or communities on statistical basis.

2. Gleason's method has been modified with a view to have a critical distinction between the relative importance of each species that occurs in small or large areas.

3. The proposed method has been called as:

"($F \times C$) ICC: [(Frequency \times Cover) Index Community Coefficient)]".

ACKNOWLEDGEMENTS

I owe special gratitude to Prof. R. Misra, Head of the Department of Botany, Banaras Hindu University, for his most valuable guidance during the course of the present investigations.

REFERENCES

- GATES, F. C. 1949. *Field Manual of Plant Ecology*. McGraw-Hill Book Co., Inc., New York and London.
- GLEASON, H. A. 1920. Some applications of the quadrat method. *Bull. Torrey bot. Cl.* 47: 21-33.
- JACCARD, P. 1912. The distribution of the flora in the Alpine Zone. *New Phytol* 11: 37-50.
- KULCZYNSKI, S. 1937. Zespoły roślin w Pieninach.—Die Pflanzenassoziationen der Pieninen. *Bull. int. Acad. Cracovie (Acad. pol. Sci.) Ser. B (Suppl. II)* 57-203 (n.v.).

FINE STRUCTURE OF DIATOM VALVES—II

BY G. S. VENKATARAMAN, S. C. MEHTA AND N. DUTTA

Indian Agricultural Research Institute, New Delhi-12

(Received for publication on February 27, 1960)

INTRODUCTION

THE fine structure of diatom valves has been studied by a number of workers. The present communication describes the fine structure of three diatoms, viz., *Ditylum brightwellii* (West) Grunow, *Bacteriastrum hyalinum* Lauder and *Navicula cuspidata* var. *conspicua* Venkataraman, as revealed under the electron microscope. The only study of *Ditylum brightwellii* is that made by Okuno (1952). According to him the frustule of *Ditylum brightwellii* is non-locular, but he also states that the pores are closed by a porous sieve membrane with two or three pores (*cf.* his Figs. 1" and 1"). In one of these figures there are structures resembling branched growths and Desikachary (1956) suggested a reinvestigation of this diatom. *Navicula cuspidata* var. *conspicua* Venkat. was erected as a new variety by Venkataraman (1939) based on the optical microscopical studies.

OBSERVATIONS

1. *Ditylum brightwellii* (West) Grunow

The areolae in this diatom open inwards. The outer membrane of the areolae is perforated by 2-4 horse-shoe shaped sieve pores (*S*) disposed oppositely or circularly (Plate VIII, Fig. 3) and in some there are structures resembling branched ingrowths. The bridge membrane of the outer membrane consists of two parts, a rib (*R*) and a wing (*W*). The rib is quite thick and extends bilaterally to form the delicate wing.

The structure of the areolae in this form is reminiscent of the structure in *Triceratium shadboltianum* var. *elongata* (Okuno, 1953), *Biddulphia titiana* (Okuno, 1954) and *Podocystis spathulata* (Desikachary and Aleem, 1955), in having 2-4 arcuate sieve pores disposed circularly or oppositely.

Habitat.—Planktonic in estuarine waters of the rivers Hoogly and Mahanadi.

2. *Bacteriastrum hyalinum* Lauder

Frustules about 38μ in diameter with many spines. Valve surface is not areolate and shows delicate anastomosing ribs radiating from a central circular or elliptical hyaline portion as in some species of *Chaetoceros*. The valve, however, shows simple perforations near the

base of the setae (Plate VIII, Fig. 1). The pores are $0.09-0.1\mu$ in diameter. The spines are hollow and do not show any perforations (*cf.* Okuno, 1949 and 1955). They bifurcate into two after a short distance. The base of the spines is funnel-shaped and the margin of the spines is armed with small spinules (Plate VIII, Fig. 2) as in *Chaetoceros*.

Habitat.—Planktonic. Cape Comorin (Venkataraman, 1959); in the estuarine waters of the Rivers Hoogly and Mahanadi.

3. *Navicula cuspidata* var. *conspicua* Venkataraman

Frustules elliptic-lanceolate with rounded and slightly constricted ends. The striae resolved into single series of rounded to slightly elongated pores with porous sieve membranes (Plate VIII, Fig. 4). The pores are 18 in 10μ and $0.12-0.13 \times 0.13-0.16\mu$. The sieve pores are $0.008-0.01\mu$ in diameter and 60–70 in 1μ . They are arranged obliquely.

This form resembles *Navicula cryptocephala* in its fine structure (Helmcke and Krieger, 1951) and differs from the type species *N. cuspidata* and its other variety *ambigua* which have simple roundish or rectangular punctae. This variety was distinguished from the type as new by Venkataraman (1939) on the basis of a slight constriction near the poles and close longitudinal striae towards the margin than towards the middle line. The present investigation on the fine structure of this variety also confirms the separation of this form from the type. Thus the electron microscopical studies together with the classical optical microscopic investigations offer critical criteria for the systematic presentation of various diatoms.

Habitat.—Freshwater plankton.

SUMMARY

An account is given of the wall structure in three diatoms, *viz.*, *Ditylum brightwellii*, *Bacteriastrum hyalinum* and *Navicula cuspidata* var. *conspicua*, as revealed by a study with the electron microscope.

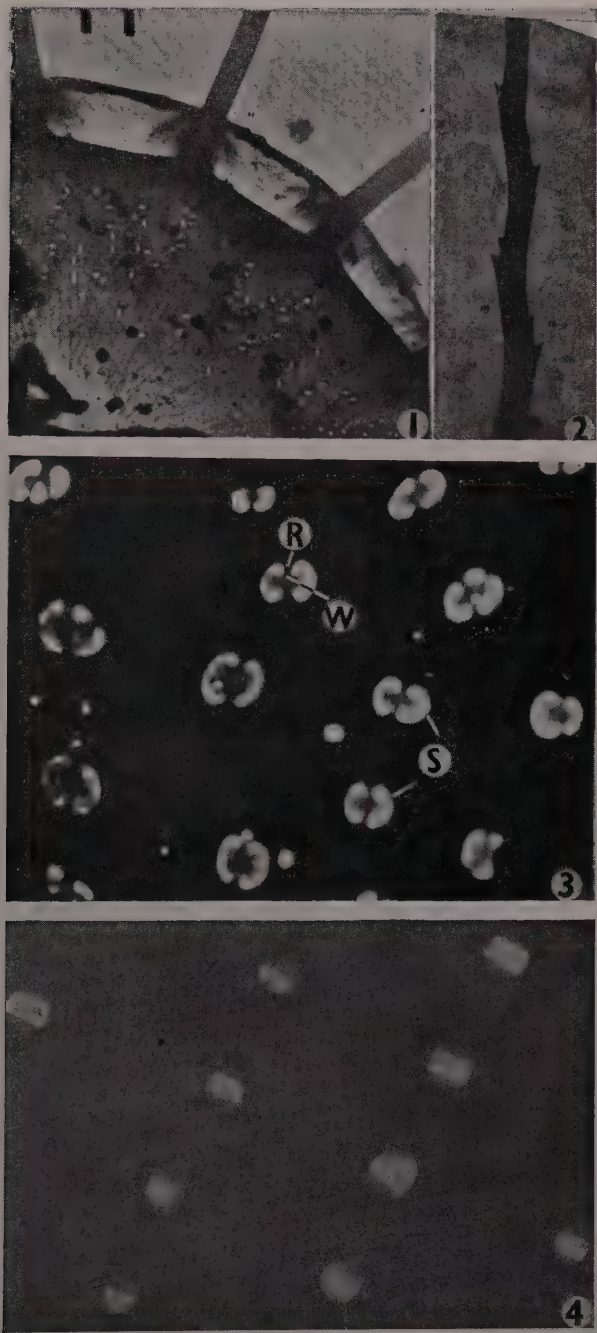
The areolae in *Ditylum brightwellii* open inwards and its outer membrane is perforated by 2–4 arcuate sieve pores.

In *Bacteriastrum hyalinum* the wall is non-areolate, but shows simple perforations near the base of the setae.

The separation of *Navicula cuspidata* var. *conspicua* from the type based on the classical optical microscopical studies is justified and confirmed by the present electron microscopical studies.

ACKNOWLEDGMENT

We are very grateful to Drs. M. S. Randhawa, B. P. Pal, A. B. Joshi, R. V. Tamahne and C. Dakshinamurti for the kind facilities, and to Dr. T. V. Desikachary for his advice and for kindly going through the manuscript.



G. S. Venkataraman, S. C. Mehta and N. Datta FIGS. 1-4

REFERENCES

- DESIKACHARY, T. V. 1954. Electron microscope study of the diatom wall structure, VI. *Mikroskopie* **9**: 168-78.
- . 1956. Electron microscope studies of diatoms. *J. roy. micr. Soc.* **76**: 9-36.
- AND ALEEM, A. A. 1955. Electron microscope study of diatom wall structure, VII. *J. Sci. industr. Res.* **14 C**: 42-46.
- HELMCKE, J. G. AND KRIEGER, W. 1951. Elektronenmikroskopische Untersuchungen über den Feinbau der Diatomeenmembran. *Ber. dtsh. bot. Ges.* **64**: 29-30.
- OKUNO, H. 1949. Electron microscopic study on fine structures of diatom frustules. VII. *Bot. Mag. Tokyo* **62**: 136-40.
- . 1952. Electron microscopic study on fine structures of diatom frustules, IX. *Ibid.* **65**: 158-63.
- . 1953. Electron microscopic study on fine structures of diatom frustules, XI. *Ibid.* **66**: 121-24.
- . 1954. Electron microscopic study of fine structures of diatom frustules, XII. *Ibid.* **67**: 172-77.
- . 1955. Fine structures of diatom frustules, *Sobi*, n. **21**: 1-7.
- VENKATARAMAN, G. 1939. A systematic account of some South Indian diatoms. *Proc. Indian Acad. Sci.* **10B**: 293-368.
- VENKATARAMAN, G. S. 1959. A contribution to the knowledge of the Diatomaceae of Kanya Kumari (Cape Comorin), India, II. *Proc. nat. Inst. Sci. India* **24 B**: 307-13.

EXPLANATION OF PLATE VIII

- FIGS. 1 and 2. *Bacteriastrum hyalinum*.
- FIG. 1. Margin of the valve ($\times 4,300$; 80 kv.);
- FIG. 2. Spine ($\times 4,875$; 80 kv.).
- FIG. 3. *Ditylum brightwellii*, areolar structures ($\times 15,000$; 40 kv.) S, sieve pore, R, rib, W, wing.
- FIG. 4. *Navicula cuspidata* var. *conspicua*, details of the punctae ($\times 45,000$; 60 kv.).

DISTRIBUTION OF VEGETATIONAL TYPES AND THEIR DOMINANT SPECIES IN EASTERN INDIA

BY *ROLLA SESHAGIRI RAO AND G. PANIGRAHI

Botanical Survey of India, Shillong

(Received for publication on February 10, 1960)

VEGETATIONAL types occurring over extensive tracts of Eastern India comprising of Orissa, Behar, Bengal, Assam, Sikkim, North-East Frontier Agency (NEFA), Manipur and Tripura and included in the Eastern Circle of the Botanical Survey of India, have been studied over the last three years and their characteristic features, noted. The areas visited so far lie within $17^{\circ} 45' - 29^{\circ} 30' \text{ N.}$ and $81^{\circ} 30' - 97^{\circ} \text{ E.}$ and comprise of altitudinal ranges varying between sea-level to 5,500 m. (18,000 ft.) showing great variations in geology, soil and topography as well as in climatic conditions. These variations in physical geography coupled with the striking effects of ecological (including biotic) factors, influence and determine the development of a number of vegetational types, the spatial distribution and chief peculiarities of which are briefly presented here.

The main types of forests met within Eastern India may be classified and the areas of their occurrence based on actual field study by the authors, can be tabulated as follows (*vide* Map I):—

TROPICAL upto 900 metres (about 3,000 feet)	Evergreen and Semi- evergreen (rain) forest	Barnihat, Umtrue, Narduar, N. Lakshmpur, Cachar, Chis- rang of Assam, Foothills of Sikkim and NEFA Himalaya, [Kameng, Subansiri, Siang, Lohit and Tirap (Patkoi Mountains) Frontier Divi- sions].
	Moist and Dry Deci- duous Forest	Sukinda, Rebna, Simlipal of Orissa, Rajmahal Hills of Bihar, Kocharigaon, Goal- para of Assam and Western Region of Tripura.
	Grassland	North Kamrup (Motharguri), Kaziranga, Orang and Foot- hills of Mikir Hills of Assam.

* Now at the Botanical Survey of India, Poona.

SUB-TROPICAL 900–1,800 metres (about 3,000–6,000 feet)	Mixed Forest	.. Region above Foothills (beyond 900 metres) Sikkim and NEFA (Sissini and surroundings and Kalaktang, of Kameng Frontier Divisions and part of Tirap).
	Pine Forest	.. Pynursla, Jowai, Shillong, Cherrapunji and parts of Nongstoin of Assam and Rupa Valley of Kameng Frontier Division (NEFA).
	Grassland	.. Nongstoin, Haflong and part of Jowai, of Khasi and Jaintia Hills of Assam.
TEMPERATE 1,800–3,500 metres (about 6,000– 12,000 feet)	Mixed Forest	.. Lachen, Lachung, Tonglu, Karponang and Gnathong areas in Sikkim and regions surrounding Peri La, Bomdi La, Singe Dzong, Jhang and Towang in Kameng Frontier Division, Hills above Apatanang Valley in Subansiri Frontier Division and higher slopes in Bori area above inner valley of Siang Frontier Division (NEFA).
	Pine Forest	.. Dirang Dzong Valley in Kameng Frontier Division, Apatanang Valley (cultivated) in Subansiri Frontier Division and beyond Heyuliang up to Walong along inner valley of Lohit Frontier Division (NEFA).
SUB-ALPINE 3,500–4,500 metres (about 12,000– 14,500 feet)		Thangu, Yumthang, Sandakphu, Changu and Kupup surroundings in Sikkim, lower Se La area, Jhang Valley and above Towang and Mago in Kameng Frontier Division and above Walong in Lohit Frontier Division.
ALPINE 4,500–5,500 metres (about 14,500– 18,000 feet)		Donky La, Lona La, Jongri, Zemu-Lhonak Valleys, Nathu La, Zelang La surroundings in Sikkim, Bum La, Pangchen, Chuna areas of Kameng Frontier Division and Upper Delei and Dichu Valleys in Lohit Frontier Division (NEFA).



EASTERN CIRCLE

B. S. I.

DISTRIBUTION OF VEGETATIONAL TYPES IN EASTERN INDIA

- | | | | |
|--|---|--|--------------------------|
| | Tropical Evergreen & Semievergreen Forest | | |
| | Tropical Moist & Dry Deciduous Forest | | Subtropical Mixed Forest |
| | Subtropical Pine Forest | | Temperate Mixed Forest |
| | Temperate Pine Forest | | Sub Alpine |
| | Alpine | | |
| | Tropical Grassland | | Sub Tropical Grassland |

MAP I. Eastern India showing main types of forests as studied by the Botanical Survey of India, Eastern Circle, during 1956-59.

Tropical evergreen and semi-evergreen forest.—Although tropical evergreen or semi-evergreen forest is the climax type of vegetation in the rain forests of Assam plains and foothills of Sikkim and North-East Frontier Agency (NEFA), it has suffered greatly due to the effect of physiographic, edaphic and biotic factors operating in the region. Accordingly these are now restricted to inaccessible hills and valleys and find optimal expressions along the course of hill streams unsuitable

for cultivation or to areas protected as reserved forests. Accordingly, forests of Barnihat, Umtrue, parts of South Kamrup District and Narduar reserved forest in Sibsagar District, Ranga, Kakoi, and Dulong reserved forests in North Lakhimpur District, parts of Cachar District and Chirang reserved forest in Goalpara District of Assam, foothills of Sikkim and NEFA Himalayas comprising of Kameng, Subansiri, Lohit and Tirap (including Patkoi ranges) Frontier Divisions may be classified under Evergreen and Semi-evergreen types. These forests are characterised by thick impenetrable vegetation, comprising of tall tree species up to 20–30 metres high forming the top canopy, of shrubs, a large number of climbers, lianes, and epiphytes in the middle storey and of an evergreen forest floor made up of moist humus cover supporting ground vegetation.

The highest storey consists of tall species of *Dipterocarpus turbinatus*, *Euphoria longana*, *Canarium resiniferum* in Katakhal reserved forest of the Cachar District and species of *Kayea assamica*, *Castanopsis*, *Bridelia*, *Terminalia chebula*, *Pterospermum*, *Dysoxylum* and *Mesua ferrea* in the North Lakhimpur reserved forest. Similarly, species of *Sterculia*, *Dysoxylum*, *Phoebe*, *Gmelina*, *Pterospermum*, *Dillenia*, *Amoora*, *Salmalia* form dominants in the Chirang reserved forest whereas *Mesua ferrea*, *Amoora wallichii*, *Stereospermum chelonoides*, *Artocarpus chaplasha*, *Toona ciliata* and *Lagerstroemia speciosa* are some of the important species in the Narduar reserved forest of Assam. The foot hills of the Kameng Frontier Division are dominated by species of *Ficus* and *Quercus*, *Sterculia villosa*, *Lagerstroemia parviflora* whereas those of the hot river valleys of the Lohit and Siang Frontier Division (NEFA) are featured by *Terminalia myriocarpa*, *Dipterocarpus*, *Caryota* and *Pandanus* mixed with a few species of *Musa* and those of Tirap Frontier Division (NEFA) by *Bambusa*, *Calamus*, *Daemonorops*, *Stereospermum* and *Anthocephalus cadamba*. However, species of *Ficus*, *Syzygium*, *Duabanga*, *Terminalia* together with a few bamboos and palms may be enumerated as common to all these forests.

Tropical moist and dry deciduous forest.—The forests of Tripura, Goalpara and Kocharigaon of Assam, Rajmahal Hills of Bihar and Sukinda, Rebna and Simlipal reserved forests of Orissa are ascribed to these types of forests. The general vegetation of these areas (except Simlipal forest and parts of Rebna forest bordering upon Meghanada Parbat) is secondary due to intensive human interference. The Sal (*Shorea robusta*), the most predominant tree crop, forms extensive reserves extending over hundreds of acres in all these forests. The principal associates of Sal are *Careya arborea*, *Gmelina arborea*, *Altingia excelsa*, *Sterculia villosa*, *Salmalia malabarica*, etc., together with *Eupatorium odoratum* in Assam, whereas in the Rajmahal Hills of Bihar, *Madhuca latifolia*, *Terminalia tomentosa*, *T. belerica*, *Diospyros melanoxylon*, *Semecarpus anacardium*, *Bauhinia* spp. and *Acacia* spp. form the principal associates. The Sal in Sukinda and Rebna reserved forests, on the other hand, is associated with *Diospyros tomentosa*, *Careya arborea*, *Schleichera trijuga* and various species of *Terminalia* together with *Anogeissus latifolia*, *Pterocarpus marsupium*, *Ougeinia oojeinensis*, *Syzygium cumini*, *Michelia champaca*, *Dillenia pentagyna*, *Adina cordi-*

folia, etc., in the southern parts whereas *Phoenix* species and various grasses form thick cover in Sal forest floor in the northern tracts of the Simlipal forest.

Similarly, *Schleichera oleosa* and *Madhuca indica* among trees and *Bauhinia vahlii* and *Combretum decandrum* among the lianes are very common in the Orissa and Bihar forests whereas they are seldom met with in the similar types of forests of Assam. Again, *Cochlospermum religiosum* is met with as a rare species near Bangiriposi area in the Simlipal forest.

The reserved forests of Tripura adjoining Cherilam, and Radhakishorepur comprise of *Garuga pinnata*, *Lannea coromandelica*, *Schima wallichii*, *Albizia procera*, *Microcos paniculata*, etc., not met with in corresponding forest types in Assam and NEFA whereas *Dillenia pentagyna*, species of *Terminalia*, *Careya arborea*, *Lagerstroemia parviflora*, etc., are common to all.

Tropical grassland.—The grassland met with in reserved forests of Motharguri, Orang as well as in the foothills of Mikir Hills may be termed as secondary, arrested at a sub-climax stage due to intensive operation of biotic factors whereas the extensive grassland of Kaziranga is an edaphic climax conditioned and influenced by the wide swampy area consisting of several stagnant pools.

The principal components of the grassland of foothills of Mikir Hills are the grasses, bamboos and ferns. There are a few trees and shrubs, represented by species of *Vatica*, *Ficus*, *Antidesma*, *Styrax* and *Artocarpus*.

Kaziranga reserve is a swamp with *Sclerostachya fusca* and *Saccharum spontaneum* as the most dominant species. This grassland with the grass attaining 5 m. in height extends over miles and harbours *Rhinoceros unicornis* as one of the most important and rare species of animals. The shrubby and herbaceous species met with in Kaziranga reserve are those of *Desmodium*, *Crotalaria*, *Acacia*, *Zizyphus*, *Fluggea*, *Cyanotis*, *Alternanthera*, *Eclipta*, etc. Along the small water ponds which are quite common, the aquatic plants like *Ottelia*, *Eichhornia*, *Monochoria*, *Jussieuia*, and *Nymphaea* are some of the prominent species.

The grassland of Motharguri game sanctuary in the North Kamrup reserved forest is, however, not the climatic climax. This is purely the outcome of extensive destruction both by natural calamities (flood and fire) and biotic influence (felling and grazing) of moist deciduous or semi-evergreen forest, the type which normally develops under the climatic and edaphic conditions existing in this area. The area for the first three miles from Bansbari to Motharguri is covered by extensive grassland composed of mainly tall grass species of *Saccharum*, *Narenga*, *Apluda*, *Themeda*, *Erianthus*, etc., mixed with a few tall herbaceous species of *Leea*, *Clerodendrum*, *Melastoma*, *Ageratum*, etc., covered by the most predominant climber, *Mikania cordata* (Burm.) B. L. Robinson (a weed with nuisance value killing the seedlings of forest department plantations), without any trace of trees for miles on either side of the track

except a few stunted trees of *Salmalia malabarica*. At certain regions towards the east and south-west near Phulguri area, the tree growth is quite dense composing of *Dillenia*, *Careya*, *Acacia*, etc., together with *Schima*, *Lagerstroemia*, *Terminalia* and others.

Sub-tropical mixed forest.—The forests of Sissini and its surroundings and the region to the west of Kalaktang adjoining Bhutan border in the Kameng Frontier Division, inner valleys of Siang and Lohit Frontier Divisions, parts of Tirap Frontier Division along the Patkoi ranges in the Burma border, are of sub-tropical mixed types. These are dominated by *Ficus-Castanopsis-Callicarpa* association in the lower ridges and by *Schima-Castanopsis-Engelhardtia-Sarauja* association in the higher ridges up to 1,800 metres. Species of Araliaceae are generally common to all. But in areas with drier aspects of hills, *Rhododendron arboreum* and *Lyonia-Pieris* spp. together with a species of *Sarauja* predominate whereas the deep river valleys are featured with species of *Morus*, *Albizzia*, and bamboos in the Kalaktang area. On the other hand, species of Magnoliaceae and Ternstroemiaceae together with bamboos with very few *Rhododendron* and *Lyonia* species occur in the Tirap area.

Along the inner valley of Lohit Frontier Division species of *Quercus* are quite common mixed with a few species of *Musa*. In the Siang Frontier Division, the inner valley along the Siang river bed even after approaching India-Tibet border presents sub-tropical type of vegetation mixed with a few temperate species. Palms like *Livistona* and *Caryota* are commonly mixed with a few species of *Musa*, *Dillenia*, *Macaranga*, *Acer*, etc. Luxuriant growth of *Erianthus arundinaceus* on the cleared and burnt areas along the interior valley even near Tibet border is an interesting observation.

Sub-tropical pine forest.—The forests of Jowai, Pynursla, Cherrapunji, and Nongstoin areas in the Khasi and Jaintia Hills of Assam as well as the Rupa Valley in the Kameng Frontier Division of NEFA may be classified under this category. *Pinus insularis* (= *P. khasya*) is the most dominant species in the Khasi and Jaintia Hills whereas *Pinus wallichiana* (= *P. excelsa*) is found in the Rupa Valley area along with *Rhododendron arboreum*, *Lyonia Berberis*, *Quercus griffithii*, and members of Rosaceae. The associates of *Pinus insularis* in the Khasi and Jaintia Hills are *Schima wallichii*, *Elaeocarpus*, *Ternstroemia*, *Quercus*, *Cinnamomum*, *Engelhardtia* together with shrubs like *Symplocos*, *Rosa*, *Eurya*, etc. Orchids are quite common with profuse development of species of *Dendrobium*, *Phaius*, *Paphiopedilum*, *Vanda caerulea*, *Cymbidium*, *Otocilus* and several others.

Occasionally, *Acer* spp., generally found in the temperate regions, start their lower limit in these forests or there is a return to the mixed semi-evergreen type with a large number of climbers, and lianes, featured with epiphytic mosses, ferns and orchids wherever a humid corner can be located, as seen near about Rupa Valley and on the way to Bomdi La beyond Horseflat as well as to the west of Jegaon in Kameng Frontier Division (NEFA).

Sub-tropical grassland.—The grasslands surrounding Nongstoin, Haflong and Jowai in the Khasi and Jaintia Hills of Assam extend over miles in all directions and covers the bare rounded tops of low hills and vales over wide areas, interspersed occasionally by patches of sub-tropical mixed forest here and there which represent the climatic climax type of the area. The grassland in these areas is a biotic climax owing its origin to the practice of shifting cultivation or “Jhuming” of the native tribes. The pockets of mixed forest are now found in the shelter of hill slopes which are unsuitable for jhuming because of their steep nature or which are too far away from human habitation to escape the onslaught of the human agency from his hunger for more fuel and food. The rest of the country presents almost a pure grassland vegetation, ranges after ranges of hills being covered over by a few species of grasses, attaining about knee-deep height at places. There is not a single shrub or broad-leaved herb mixed with grass species, although at points species of Zingiberaceae, Liliaceae, Burmanniaceae, Juncaceae and Cyperaceae together with a few species of *Impatiens*, Compositae, Polygonaceae and Piperaceae colour the green valleys.

Thus, it may be seen that the effect of climatic, edaphic and biotic factors on the development of vegetational types may be profound and may not only change the type of vegetation but also within the same vegetational type, the dominant floristic components may become variable to a great extent.

Temperate mixed forest.—Ranges surrounding Lachung, Lachen, Tonglu, Karponang, and Gnathong of the Sikkim Himalayas, Bomdi La, Jhum La, Singe Dzong and Jhang in the Kameng Frontier Division and the hills surrounding Apatanang Valley in the Subansiri Frontier Division and higher slopes in Bori area above inner valley of Siang Frontier Division of the NEFA Himalayas may be ascribed to temperate mixed type of forest. Species of *Acer*, *Juglans*, *Rhododendron*, *Quercus*, *Betula*, *Magnolia*, *Michelia* and several others together with *Arundinaria* and other species of bamboos characterise the hill tops and valleys of the temperate ranges of the Eastern Himalayas.

The temperate vegetation on the mountain slopes of the Apatanang valley comprises of *Amoora wallichii*, *Alnus nepalensis*, *Syzygium tetragonum*, *Ilex theaeifolia*, *Medinilla himalayana* and *Ficus hookeri*.

The composition of the temperate forest gradually changes as the altitude increases and *Rhododendron*-*Pyrus*-*Rosa*-*Spiraea*-*Tsuga* association becomes dominant up to 3500 m.

Plagiogyria adnata together with *Dryopteris* spp. form dense covering in the humus-covered-forest floor in these forests. While the epiphytic mosses, ferns and lichens are common, epiphytic orchids are rather less frequent than in tropical and sub-tropical forests.

Temperate pine forest.—The forests found in the valleys of the Dirang Dzong of Kameng Frontier Division, Apatanang of Subansiri Frontier Division, inner valley of Lohit beyond Heyuliang up to Walong of the Lohit Frontier Division in the NEFA Himalayas belong to typical

temperate pine forest type. Along the edges of the Apatanang Valley, *Pinus wallichiana*, and species of *Bambusa* are extensively cultivated. The valley being under rice cultivation, the herbaceous flora as weeds along cultivated fields and stagnant watery places consist primarily of *Cardamine trifoliata*, *Viola patrinii*, *Hypericum japonicum* and *Coix lachryma-jobi*. On the other hand, Dirang Dzong Valley lying, along the inner ranges of the NEFA Himalayas and experiencing less rainfall, is dominated by *Pinus wallichiana*, associated with *Rhododendron arboreum*, *Quercus griffithii*, *Q. helferiana* and species of *Lyonia*. This is one of the most ideal zones suitable for profuse development of epiphytic orchids such as *Dendrobium*, *Cymbidium*, *Bulbophyllum*, *Vanda*, *Eria*, *Phalaenopsis* and many others. In Lohit Valley along the slopes between Heyuliang and Walong, *Pinus wallichiana* is predominant mixed with a few species of *Rhododendron* and others.

Sub-alpine type.—This type of vegetation necessarily is of restricted distribution in the Indian flora and is confined to higher ranges of the Himalayas. Ranges surrounding Thangu, Yumthang, Sandakphu, Changu and Kapup areas in the Sikkim Himalayas and higher ranges above Singe Dzong towards Se La, Jhang Valley, Towang and Mago areas of Kameng Frontier Division and above Walong in Lohit Frontier Division of the NEFA Himalayas present the sub-alpine type of vegetation. Tall trees of *Abies densa* form the dominant component for most of this type of vegetation associated with shrubby and bushy species of *Rhododendron*, *Juniperus*, *Berberis*, *Salix*, *Cotoneaster*, *Lonicera* and a few others. This range of altitude favours the growth of herbaceous species of *Anemone*, *Aconitum*, *Cassiope*, *Primula*, *Potentilla*, *Pedicularis*, *Mecanopsis*, *Corydalis*, etc., as small, sometimes stunted, clumps.

Alpine type.—Vegetation from the sub-alpine region gradually merges, with the complete disappearance of tree growth, into the Alpine type as the altitude increases from 4,500 m. up to 5,500 m. which is more or less the limit of plant life in the area under study. Higher ranges surrounding Donky La, Lona La, Jongri, Zemu and Lhonak Valleys, Nathu La and Jelap La of the Sikkim Himalayas, Bum La, Pangchen and Chuna areas of Kameng Frontier Division, Upper Delei and Dichu Valleys of Lohit Frontier Division of the NEFA Himalayas present typical Alpine moorland type of vegetation consisting of Dwarfed association of straggling and hardy cushions with thick, perennial, deep root stocks of a few herbaceous species of *Rheum*, *Arenaria*, *Saussurea*, *Ephedra*, *Saxifraga*, *Sedum*, *Festuca* and a few others mixed with stunted crawling bushes of *Rhododendron anthopogon* and *R. nivale*.

Distribution of some rare and interesting species in Eastern India (vide Map II).—A Study of some of the rare and interesting species in the forests of Eastern India establishes the discontinuous nature of their distribution in this region. Brief notes on the distribution of a few selected species only on the basis of collections available in the Eastern Circle Herbarium but not recorded so far, are given below.



PART OF
EASTERN CIRCLE
BOTANICAL SURVEY
OF INDIA.

Scale 0—40 Miles.

- | | | |
|----------------------------|-------------------------------|----------------------------------|
| ● <i>Gnetum gnemon</i> | + <i>Nepenthes khasiana</i> | ○ <i>Balanophora involuerata</i> |
| ★ <i>Drosera peltata</i> | □ <i>Monotropa uniflora</i> | ▲ <i>Dischidia rafflesiana</i> |
| % <i>Vanda caerulea</i> | ■ <i>Taxillus vestitus</i> | 8 <i>Podophyllum hexandrum</i> |
| S <i>Galcola falconeri</i> | ☀ <i>Aeginetia indica</i> | ☺ <i>Psilotum nudum</i> |
| Δ <i>Phaius mishmensis</i> | W <i>Fritillaria cirrhosa</i> | ↑ <i>Dipteris wallichii</i> |
| ◎ <i>Coptis teeta</i> | ∪ <i>Balanophora dioica</i> | ◆ <i>Boschniakia himalaica</i> |

MAP II. Part of Eastern Circle of Botanical Survey of India, showing the distribution of some of the rare and interesting species.

While *Gnetum montanum* Markgraf is almost common among the lianes in the eastern tropical forests of the country, *Gnetum gnemon* Linn. is seldom met with and has so far been collected from a few reserved forests (150–300 metres altitude) of Kocharigaon and surroundings of Darrang District, Garampani and Barpathar of Sibsagar District, Mikir Hills area, Cachar District and also Naga Hills region.

Among the Indian carnivorous plants *Nepenthes khasiana* Hook.f., the pitcher plant, has a very restricted distribution in India and is mostly limited to the Garo, the Khasi and the Jaintia Hills of Assam within an altitude of 900–1,200 metres on somewhat swampy spots near Jorain in Jaintia Hills, Long Rien, Nong-hulen in the Khasi Hills, Bagmara, the Simsang river bank at Nongwalbibra in the Garo Hills where the pitcher plant grows quite in abundance. It is quite possible that the species may be occurring in some more localities in these hills which can be traced by further exploration. On the other hand, *Drosera peltata* Sm. grows quite commonly along higher altitudes (about 1,500 metres) in Khasi Hills near Shillong, Cherrapunji and other surroundings and interestingly enough this species has been collected from moist slopes on the way to Thanka La from Lachung in North Sikkim and also along grassy slopes on the way to Towang from Jhang in Kameng Frontier Division (NEFA), both at an altitude of about 3,000 metres. In the grasslands of Nongstoin area, Khasi Hills (1,400 metres) the plants growing on sandy alluvium, attain an unusual height of about 30 cm. *Dischidia rofflesia* Wall., another species of unusual interest, is very scarce and occurs as an epiphyte on *Ficus*, *Artocarpus*, *Vitex* and *Careya* in a few reserved forests of Goalpara (Dhupdhora), Kamrup (Rajpara Forest Inspection Bungalow) and Nowgong Districts of Assam plains.

Among root parasites, *Balanophora dioica* Br. is rather a common species in the genus and has been found to be growing in large clumps in semi-dark or shady wet humus-covered forests (altitude 900–1,500 metres) of the Khasi and Jaintia Hills, Bemdi La and Rahung area of Kameng Frontier Division (NEFA), Heyuliang area in Lohit Frontier Division and sometimes in profuse quantities as found near Eyo (450 metres), Bori area of Siang Frontier Division (NEFA). *Balanophora involucrata* Hook.f., (sp. ?), a larger species, appears to have very restricted distribution and has been collected from dark humid forest floor below Tuting village and surroundings (900 metres) in Siang Frontier Division and along Raho-Waka Hills in Tirap Frontier Division (NEFA). *Boschniakia himalaica* Hook.f. and Thom. is an interesting obligate root parasite, characteristically growing on the roots of *Rhododendron* species only. Along the upper temperate *Rhododendron* belt of the Himalayas (3,500–4,800 metres), this species was collected at a few places in North and Eastern Sikkim, below Se La and above Towang of the Kameng Frontier Division (NEFA). Another root parasite *Aeginetia indica* Roxb. which grows mostly on grass roots is widespread and occurs abundantly on sandy-alluvium in shady humid spots along the mixed forests of Chirang reserve in Tripura State, near Niusa of Tirap Frontier Division (NEFA), Motharguri of North Kamrup reserve

forest, Assam, near Kohima in Naga Hills and a few places in Khasi Hills.

Of the several stem parasites collected so far, *Taxillus vestitus* (Wall.) Danser has been collected from a few interesting localities such as hill slopes above Apatanang Valley (1,800 metres) of Subansiri Frontier Division (NEFA) and near Kohima in Naga Hills besides a few areas in Khasi and Jaintia Hills of Assam.

Saprophytes like *Monotropa uniflora* Linn. are rare and occur in the dense humus-covered shady forest floor (1,200–1,500 metres) near Mawphlong in Khasi Hills of Assam, in Mungpo area of Darjeeling District in the Eastern Himalayas, whereas the tall saprophytic orchid *Galeola falconeri* Hook.f. with its deep yellow flowers stands out majestically amidst wild banana plants in the humid forests of Sissini (1,400 metres) of Kameng Frontier Division (NEFA) and also from Aka Hills, a region adjacent to Sissini area.

Interesting orchids like *Phaius mishmensis* Rechb.f. have been gathered not only from remote areas of Mishmi Hills (4 000–6,000 m.) such as Heyuliang area in Lohit Frontier Division and also Eyo area of Bori region in Siang Frontier Division (NEFA) but also from Bomdi La-Rahung area (1,500 metres) in Kameng Frontier Division (NEFA) and a few places in Khasi Hills and Digboi reserve of Assam plains. *Vanda caerulea* Griff., the highly prized blue orchid of Asia, which has been so far reported from the Khasi and Jaintia Hills of Assam and also the Naga Hills area (1,500 metres) turns up as a new find in the Niusa area (1,400 metres) and Chenglang of Tirap Frontier Division (NEFA).

Several important medicinal plants have so far been collected from Eastern India. The distribution of *Podophyllum hexandrum* Royle (= *P. sikkimensis* Chatterjee et Mukherjee) with the Sikkim Himalayas so far recorded as the extreme eastern boundary has been extended further east on the basis of its collection in the Se La-Jhang Valley (3,600 metres) of the Kameng Frontier Division (NEFA). Similarly, *Coptis teeta* Wall. (Mishmi teeta of commerce) grows quite in abundance in the sub-temperate slopes (1,500–2,000 metres) of the entire Mishmi Hill-ranges of the Dibhang and Lohit Frontier Divisions (NEFA). *Fritillaria cirrhosa* D. Don which is of late considered to be possessing medicinal properties of unusual interest is an upper temperate or even sub-alpine species growing at altitudes between 3,500–4,500 metres and has been collected from high altitudes of Northern and Eastern Sikkim, Se La area in Kameng Frontier Division and Dichu Valley and surroundings in Lohit Frontier Division (NEFA).

Among the pteridophytes, the primitive *Psilotum nudum* (L.) Beauv. (= *Psilotum triquetrum* Sw.) generally reported to occur throughout the tropics and sub-tropics of both hemispheres, has been collected in the remote Siang river valley beyond Geling (800 metres) almost near Tibet border in the Siang Frontier Division (NEFA). The shade-loving fern, *Dipteris wallichii* (Br.) Moore, a species with discontinuous distribution in the world flora, though very much localised in its

development, has been found to be growing abundantly in the Baha Hills (1,400 metres) of Kalaktang area in Kameng Frontier Division (NEFA), in Jaintia Hills near Jowai (1,000 metres) and in Tipong reserve forest (300 m.) beyond Margherita of Assam.

SUMMARY

The distribution of important vegetational types met with in the different parts of Eastern India comprising of Orissa, Bihar, West Bengal, Assam, Sikkim, North-East Frontier Agency, Manipur and Tripura, visited by the Eastern Circle of the Botanical Survey of India up to March 1959, for purposes of botanical collection and study, have been discussed in the paper.

Within the framework of the classification of vegetational types, traditionally based on altitude and latitude, the different areas visited have been ascribed to one or more of forest types and their different dominant species components have been briefly enumerated and discussed, thus illustrating the well-known interrelationships between "vegetation and flora".

The all-important role of biotic factors in transforming the climatic climax and arresting the development of evergreen or semi-evergreen type at the grassland stage as observed in parts of Tirap Frontier Division, NEFA and in Nongstoin and other areas of the Khasi and Jaintia Hills of Assam (where certain higher and suitable elevations terminate into Pine forest) and also the influence of edaphic factors in the development of extensive grasslands in Motharguri (North Kamrup Reserve) and Kaziranga Reserve of Assam, with over 4 metres tall grass species of *Sclerostachya fusca* and *Saccharum spontaneum*, have been explained. Similarly, notes on the development of small pockets of unusual forest types not characteristic to those altitudes but mainly due to the effect of local micro-climate have been added.

The distribution of some of the rare and interesting species in Eastern India exclusively on the basis of collections made by the Eastern Circle, Botanical Survey of India, since 1956, namely, *Gnetum gnemon*, *Nepenthes khasiana*, *Drosera peltata*, *Dischidia rafflesiana*, root parasites like *Balanophora involucrata* (?), *B. dioica*, *Boschniakia himalaica*, and *Aeginetia indica*, stem parasites like *Taxillus vestitus* and saprophytes like *Monotropa uniflora* and *Galeola falconeri*, interesting orchids like *Phaius mishmensis*, *Vanda caerulea*, medicinal plants like *Podophyllum hexandrum*, *Coptis teeta* and *Fritillaria cirrhosa*, and rare members of Pteridophytes, such as, *Psilotum nudum*, and *Dipteris wallichii*, have been indicated.

Grateful thanks are due to Dr. J. C. Sen Gupta, Chief Botanist, Botanical Survey of India, Calcutta, for his keen interest and encouragement for preparation of this work for publication.

REVIEWS

Illustrated Genera of Imperfect Fungi. By H. L. Barnett. Second Edition. (Burgess Publishing Company, Minneapolis 15, Minn.), 1960. Pp. i-iii + 225, 462 Figs. Price 4.50 dollars.

There has been a growing interest in Imperfect Fungi in recent years as shown by the numerous papers on this group which have appeared recently and the many new species and genera which have been described or old ones which have been collected again or redescribed. The appearance of this second edition of Barnett's *Illustrated Genera of Imperfect Fungi* reflects the same interest and would be welcomed by those who wish to have a reference guide to the identification of Imperfect Fungi. The identification of these fungi is difficult and the extensive revisions that have been proposed from time to time and the nomenclatural changes suggested by different workers add to the difficulties. They also add to the difficulties in summing up information for a manual like Barnett's. The present edition is of the same pattern as the first one, but is enlarged to include a larger number (462) of genera which are classified in five groups: Conidial Phycomycetes, Moniliales, Sphaeropsidales, Melanconiales and Mycelia sterilia. The main text of the book consists of brief descriptions of the genera together with citations to useful literature and line drawings which are for the most part redrawn by the author himself from various sources. The text follows a key to the genera treated in the text: the key is based on the traditional Saccardoan system, notwithstanding recent proposals to modify it. There is an excellent list of references which includes largely recent literature useful in the identification of Imperfect Fungi. Finally, there is an alphabetical index to the genera with an indication of the genus number cited in the text.

Taxonomy is exacting in its requirements and ideals and therefore it is nice to see an attempt like this to provide a guide to the identification of Imperfect Fungi relatively free from errors, considering the magnitude of the task. There are, however, some blemishes which will have to be rectified in another edition. For instance, recent work suggests that we may discard some genera such as *Pachybasium* Sacc. (= *Trichoderma*), *Gliocladiopsis* Saksena (= *Cylindrocarpon*), *Bisporomyces* van Beyma (= *Chloridium*), *Phragmocephala* Mason and Hughes (= *Entlophragmia*), *Spondylocladium* Mart. (= *Stachylidium*), *Heterosporium* Klotzsch (= *Cladosporium*), *Exosporium* Link (= *Helminthosporium*), *Sirodesmium* de Not. (= *Coniosporium*), *Sporocybe* Fr. (= *Periconia*), *Cerebella* Ces. (= *Epicoccum*), etc. Most of the papers in which these suggestions about synonymy have appeared have been quoted by the author, but it is not clear why the author has not followed these authors. *Scolecotrichum* Kunze is a *nomen confusum* (fide Hughes) and *Zygodesmus* Corda is a *nomen dubium* (fide Rogers) and yet they are acceptable to the author! As Rogers has pointed out, there is no

such thing as *Monotospora* Sacc. (see page 92) and it is surprising to find this name surviving in literature. The descriptions of some of the genera could have been more precise such as that of *Periconia* on p. 92, of *Acremoniella* and *Echinobotryum* on p. 94, and *Dwayamala* on p. 102. There is no mention of acropetal chains of conidia or the conidia maturing from apex downwards in the chains in the case of *Periconia*, a feature stressed by Mason and Ellis. Maturing of conidia from apex downwards is seen also in conidial chains of *Dwayamala*, but this is not mentioned. *Echinobotryum* is a state of *Stysanus* and *Acremoniella* has a phialospore stage, again facts which are not mentioned. Several generic (and specific) names are misspelt, e.g., *Pseudobotrys* for *Pseudobotrytis* (pp. 21, 108, 109, 224). *Orbiomyces* for *Orbimyces* (pp. 21, 128, 129, 224). *Actinoceps* for *Actiniceps* (pp. 24, 144, 145, 221), *Aristotoma* for *Aristastoma* (pp. 30, 180, 181, 221), etc. The authority for some generic names is omitted, e.g., *Nematoctonus* (p. 46), *Candelabrum* (p. 80), *Dictyoarthrinium* (p. 122), *Heptaster* (p. 132), etc. More careful proof-reading would have certainly eliminated the many printer's devils.

Notwithstanding these shortcomings, the discerning mycologist will find this new edition a useful guide for the purpose for which it is intended. No one should avoid referring to original papers and the older classical mycology texts, monographs and *Icones* and the references cited at the end of the book should enable one to go deeper into the subject and gain further details before a final identification is arrived at. It must be admitted that at present there is no other manual of this type dealing with Imperfect Fungi and Dr. Barnett is to be congratulated in bringing out this edition which is a distinct improvement on the first edition. Considering the information, illustrations and the literature citations it contains, the price of 4.50 dollars is reasonable and I most warmly commend this not only to mycologists and plant pathologists but also to those teaching and learning systematic mycology in colleges and universities.

C. V. SUBRAMANIAN

Illustrated Genera of Rust Fungi. By George B. Cummins. (Burgess Publishing Company, Minneapolis, Minn.), 1959. Pp. ii + 131. Price \$ 4.50.

The two earlier taxonomic accounts of the rust fungi are Dietel's in "Die Natürlichen Pflanzenfamilien" and Thirumalachar and Mundkur's in the *Indian Phytopathology*, 1949 and 1951. The former is in German and is also somewhat out of date now, while the latter being in a journal has not been widely available. The present book by an eminent uredinologist is therefore a welcome addition to the literature on this important group of fungi.

The concise introduction touches upon spore forms, life-cycles, a brief exposition of Tranzschel's law and correlated species, host plant and rust associations and taxonomic problems in the rust fungi. The treatment of the genera is not taxonomic as the book is not intended as a critical revision of the genera nor an attempt at natural classification

but as a guide for identification of rusts. As such, no families, tribes, etc., are described but the genera are put in ten sections based on the nature and arrangement of the teliospores. The genera in each of the sections are keyed out based on a number of characters of the several spore forms. Ninety-five genera of rusts are recognised. Several genera have been reduced to synonymy, a partial list of which is provided at the end of the book. A diagnosis of each genus is followed by citation of type species and very brief notes on taxonomic relationships and host range of the genus. This is followed by references to important literature.

Illustrations are provided for every genus. These consist of very clear schematic sketches, camera lucida drawings or photomicrographs. These illustrations form one of the most useful parts of the book as they very clearly bring out the differences and similarities between genera and thus aid identification. A list of references on descriptive manuals, regional lists and a glossary are provided towards the end of the book.

The book is a model of clarity and brevity combined with thoroughness. It will be indispensable to uredinologists but will also be very useful to workers in other branches of mycology and plant pathology. The printing and get-up are excellent.

K. RAMAKRISHNAN.

Flora Malesiana, Ser. II—Pteridophyta (Ferns and Fern Allies), Vol. 1 (Part 1). By R. E. Holttum. (N. V. Erven P. Noordh off Groningen, The Netherlands). December 1959. Pp. i-xxiv, 1-64, 32 Figs. Price Dfl. 10, £ 1, U.S. \$ 2.65.

The publication of the series *Flora Malesiana* from 1948 onwards has been acclaimed all over the world as a masterpiece of comprehensive taxonomic treatment of the botany of the Malayasian region. The present volume on Pteridophyta by the eminent Pteridologist, R. E. Holttum, would contribute significant new data on the Pteridophytes of the region in general.

The volume is divided into ten chapters. Chapter 1 is merely an introductory note of one page wherein the author has indicated the difficulties in presenting a "final scheme of classification" at this stage or given to plan in advance the precise sequence of presenting various families or orders of Pteridophytes.

Chapter 3 enumerates detailed morphological features of taxonomic interest in ferns, although many preliminary details (*viz.*, a fern stem may be long and creeping or climbing—in which case it is usually called a rhizome at page III) could have been avoided and the chapter of 8 pages condensed to essential points to illustrate phylogenetic trends in comparative morphology.

The 179 genera of Malayasian Pteridophytes are listed in Chapter 2. Of these 107 genera are distributed into 16 groups arranged alphabeti-

cally, the knowledge of their precise phylogenetic sequence being largely in a fluid state, if not chaotic.

Chapters 4 and 5 offer two alternative general keys for Pteropsida, the former based on epiphytic or terrestrial habit, the latter mostly on morphological and anatomical features. Chapter 6 provides a very useful practical key to the individual genera and would aid field botanists for easy keying down their collections to the generic level.

Chapter 7 catalogues the books and papers published on the taxonomy of Malaysian ferns after 1934.

Chapters 8, 9, and 10 present a synthetic approach for the revision of the families Gleicheniaceae, Schizaeaceae and Isoetaceae—the revision of the last family having been contributed by late A. H. G. Alston. The revision is very comprehensive in its scope presenting data on fossils, geographical distribution, ecology, vegetative morphology, sporangia, spores, gametophytes, cytology and anatomy. Keys to species and varieties, together with profuse illustrations, clearly bring out the differences for their easy identifications.

There are hardly any printing mistakes except that 1975 in line 33 at page 39 should be read as 1875 and the numerals 8, 9, 10 should have preceded the captions, Gleicheniaceae, Schizaeaceae, and Isoetaceae at pages 1, 37, and 63 respectively to indicate their respective chapters.

The printing and binding are excellent and the volume would serve as a useful handbook for the taxonomists interested in Malaysian Pteridophytes.

G. PANIGRAHI.

Salt Marshes and Salt Deserts of the World. By V. J. Chapman. [Leonard Hill (Books) Limited, London and Interscience Publishers Inc., New York]. Pp. xvi + 392. Price 95 s. net.

Highly specialised habitats and their vegetation have always fascinated the ecologist. Such study of the Salt Marshes has been for evident reasons, intensively pursued in countries of their occurrence. Ever since the publication of C. W. Townsend's '*Sand Dunes and Salt Marshes*' in 1925 rapid strides have been made in understanding the ecology of halophytes, salt marshes and salt deserts. Most of the accounts are diffuse as the habitats themselves are and are isolated being written in as many languages. It is almost impossible for any writer to keep track of the ever-growing literature on the subject. The consequential duplication of efforts as is obvious in this field of study, entails undesirable expenditure, confusion and wastage of talents and time when scientific investigations are becoming more involved. Now, there will be no room for such a complaint after the publication of Professor Chapman's book.

The publication under review proceeds with four chapters on the general problems of distribution and characteristics, physiography

and development, tides and water table, and soils of salt marshes and salt deserts of the world. In discussing these the author has ably marshalled data and observations particularly of his own, in reaching conclusions. The next five chapters of which two are devoted to the British salt marshes, rightly, as Chapman gathered most of his experience on these, are descriptive accounts of high standard. A survey of the salt marshes is given in the tenth chapter together with an account of marsh fucoids and here he has succeeded in giving some philosophical thoughts to the plant communities, their biogeographical relationships and the life form. Chapter XI is a compendium of our knowledge of the physiology, autecology, cytology and other aspects of some important component species of the community. The final chapter gives an account of the economic uses of the biome including reclamation of maritime marshes for various agricultural practices. The applicability of the scientific data given in the book has been amply justified.

The publishers deserve congratulations for bringing out the volume so nicely in spite of its very large number of tables, 102 text-figures and 45 plates which are all beautifully set in appropriate places. The reading becomes easy, interesting and effective. The bibliography is sufficiently exhaustive to be of value to research workers in the field. Ecologists, conservationists, agriculturists, geologists and geographers all over the world will find it a very useful publication. Nevertheless, the contents do not justify the very comprehensive title of the book as they deal largely with aspects of plant ecology. We shall eagerly await the publication of Prof. Chapman's studies on mangroves and sand dunes of the trilogy promised in the preface.

R. MISRA

Cyanophyta. By T. V. Desikachary. (Published by the Indian Council of Agricultural Research, New Delhi). Pp. 686. Price Rs. 37.00.

The Monograph under review is decidedly a distinct contribution to the taxonomy of Cyanophyta and it fully deserves recognition from the Phycologists of this country. The Editorial Board of the I.C.A.R. for the Monographs on Algae and the author are to be congratulated for planning and undertaking this long-needed task of bringing together all the data regarding the taxonomy of this important class of Algae. Since the literature concerning the records of Indian species of Cyanophyta is so widely distributed in many scientific journals it is not easily accessible to scholars who are handicapped with a modest reference library. For such research workers this Monograph is not only a handy reference book on which they can safely rely for their information about the Indian species but also a dependable guide for the literature dealing with this branch of knowledge.

The special feature about this Monograph which is worthy of note, is that the text for each taxon is accurate and concise and apart from such details as name, author and original reference citation, the documentation is minimal and occupies reasonable space. In such a descriptive flora good illustrations are of prime importance, and one feels

very glad to note that their reproduction is quite neat and clear. The book is legibly printed on heavy gloss paper. A bibliography of more than 40 pages testifies to the extensiveness of the literature coverage by the author. The author has taken great pains to provide the reader with a complete index which increases the usefulness of the volume.

This important work will not only be indispensable to the teacher and taught of this country but also to the Phycologists of the world, because it presents a thorough scholarly account of the total accumulated knowledge regarding the occurrence and distribution of Indian species.

Although the reader, perhaps, at places may not agree with the author about the systematic rendering of certain species this in no way minimises the importance of this work. For example, many of the Coccoid genera require reconsideration about their nomenclature and position especially so after their revision by Francis Drouet and W. A. Daily in 1956. But as these suggestions are still not recognised by all the schools of Phycology, we have to agree with the author about the advisability of retaining these old nomenclature, at least for some time, till more is known about them.

Apart from this there are certain omissions, which though quite minor, have been instrumental in keeping out records of certain Indian species from the book. For example mention is not made in the present work about the occurrence and distribution of certain Algae from Bombay, Matheron, Igat Puri, Mahabaleshwar, Khandala, Poona, etc., which were collected by Hansgirg and described in 1902—[*Algologische Schlussbemerkungen. Sitzung. K. Böhm. Gesell. Wissen. Prag.*, **14**, (28): 6–15]. The book is very reasonably priced and one may rightly hope that all the lovers of Algae will be benefited by this work.

M. R. SUXENA

PROFESSOR S. K. PANDE

1899-1960

WE deeply regret to record the sad and sudden demise of Prof. S. K. Pande on the morning of November 25, 1960, at his Lucknow residence. Indian botany, particularly Indian bryology, has suffered an irreparable loss and in his death the country has lost an eminent botanist, an excellent teacher, reputed researcher, a true patriot and a thorough gentleman.

Professor Pande was born on February 14, 1899 in the village of Aihar, district Rae Bareilly (U.P.). Educated at the Canning College, Lucknow (then under the University of Allahabad) for his undergraduate course he went to the Panjab University for post-graduate studies in 1921. His early contact with the late Prof. S. R. Kashyap, at the latter Institution, evidently shaped his future academic career and he was drawn to the study of liverworts. In 1923 he joined the Lucknow University as a Demonstrator in Botany and finally retired as Professor and Head in 1959. Thereafter he was appointed as a Professor in the National Botanic Gardens and finally accepted the offer of Professorship at the University of Saugar (M.P.)—the post he held at the time of his death.

It was during his long stay at the University of Lucknow (1923-1959) that Prof. Pande assiduously worked on various aspects of Indian Bryology. His initial eminence as a bryologist came from his work on the Indian Anthocerotales but he extended his scope of work to nearly all major sections of the Bryophytes with equal facility which reflected his general grasp in this group of plants. The wide horizon of his research encompassed critical analyses of taxonomic and developmental details including investigations on ecological, cytological and phylogenetic aspects. Amidst this apparent diversity in his study the compact approach was not neglected. Towards later years he was extremely busy in preparing detailed monographic works on several genera and had already published some of his results on *Asterella*, *Riccia* and *Riccardia*.

He was an ardent naturalist, undertook extensive plant-collecting tours in nearly all parts of the country and amassed a huge collection of Bryophytes which was further supplemented by collections sent to him by individuals and institutions abroad. Unfortunately most of these collections that were under investigation remained unfinished and much valuable information has thus been lost to Indian and international bryology. Towards the later part of his stay at the Lucknow University he was also engaged in the study of the cytology of Indian Mosses in collaboration with one of his research assistants Mr. Narinder Chopra and published several papers. It is an irony of fate that in about a month's duration of Prof. Pande's death young and promising Narinder Chopra died of heart failure at the University of Tennessee,



Prof. S. K. Pande (1899-1960)

U.S.A., where he was working for advanced training in Mosses with Prof. A. J. Sharp. Prof. Pande's numerous bryological publications are marked by high professional calibre and meticulous attention to details along with excellent illustrations.

The academic attainments of Prof. Pande brought him full recognition in the country and abroad. He was a Fellow of the National Institute of Sciences of India, President, Indian Botanical Society (1958), President, Botany Section, Indian Science Congress Association (1960), expert at several Committees of the Government of India and was assigned the preparation of a Monograph on Indian Liverworts by the C.I.S.R., Government of India. He was associated with several academic, social and cultural bodies of the country. He was also member of several foreign academic bodies and was a recognized and reputed international bryologist.

Besides his bryological publications Prof. Pande published a series of articles on general botany in Hindi in the *Vishwabharati* and these provide compact but all the important details in chaste language easy to be understood by young students.

As a teacher Prof. Pande had a lucid and direct approach to the subject and he had the rare capacity to make his lectures both of high academic value and extremely fascinating.

Endowed with a robust physique Prof. Pande was always very industrious and naturally did not spare also those associated with him. He was meticulous to the core and attended to the minutest details in teaching and research. As an administrator he was thorough but full of courtesy and generosity and thus was admired and respected by his colleagues and subordinates.

During the last few months before his death there was a general deterioration in his health and the end came suddenly under very tragic circumstances through an accidental fall.

RAM UDAR.

JOURNAL OF SCIENTIFIC & INDUSTRIAL RESEARCH

A Monthly Periodical (Started in 1942) Published in 2 Parts Demy 4to
(Printed Area: 237 × 167 mm.)

A. General: Carries articles on scientific topics of current interest, review articles, reviews of scientific and technical publications, notes and news of interest to research workers and industry, summaries of annual reports of research institutions, and research papers of technological interest.

B & C. Physical and Biological Sciences: Contain original research communications from national laboratories and other research institutions.

Annual Subscription: Rs. 20.00 (Inland); £ 2 or \$ 6.00 (Foreign)

Single Copy Rs. 2.00 (Inland); Sh. 4 or \$ 0.60 (Foreign)

PUBLICATIONS DIRECTORATE, C.S.I.R.
OLD MILL ROAD, NEW DELHI-1 (INDIA)

The Indian Journal of Genetics and Plant Breeding

Founded in 1941. Contains original papers on all topics related to the improvement of economic plants such as methods of breeding new varieties and strains, cytology, genetics and statistical techniques

The Journal is issued twice a year

Subscription rate: Rupees 20 or 4.00 dollars per volume

Vol. 17 (2) contains the papers presented at the International Symposium on "Genetics and Plant Breeding in South Asia" organised by the Indian Society of Genetics and Plant Breeding and the UNESCO South Asia Science Co-operation Office at New Delhi in January, 1957. Contents include papers on the plant breeding work done in South Asia in rice, wheat, millets, maize, fibre crops, tuber crops, oilseed crops, tobacco and sugarcane and on several special topics like "Genetics, Evolution and Plant Breeding", "Genetics of Quantitative Characters", "The Biological System of Plant Introduction" and "The Problem of Assessment of Drought Resistance in Crop Plants".

The special Symposium number is printed in art paper and covers 320 pages, Price : Rs. 52 per copy (6 dollars)

Order through booksellers or to

THE INDIAN SOCIETY OF GENETICS & PLANT BREEDING
DIVISION OF BOTANY
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI-12 (India)